Final Report

for the Smart Columbus
Demonstration Program

June 15, 2021

Produced by City of Columbus

Notice

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Disclaimer

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Abstract

This Final Report for the Smart Columbus demonstration program provides a summary of how the Smart Columbus Program and its projects were executed, and identifies the purpose, objectives and findings for each. This document serves as a summary of what the program accomplished, and the benefits, successes and opportunities for both the program as a whole and for each project.

The Smart Columbus Program was funded primarily by the United States Department of Transportation (USDOT) Smart City Challenge (SCC), which provided $40 million in funding to the City of Columbus, Ohio. The challenge solicited proposals from mid-sized cities to accelerate the deployment and demonstration of smart city concepts. USDOT sought to "demonstrate how advanced data and intelligent transportation systems (ITS) technologies and applications can be used to reduce congestion, keep travelers safe, protect the environment, respond to climate change, connect underserved communities, and support economic vitality." The City of Columbus, one of seven finalists in the challenge, was selected as the winner in June 2016.

The Smart Columbus Program is a compilation of eight transportation, mobility and data projects developed to improve access to jobs, enhance the visitor experience, stimulate economic prosperity, better connect residents to safe and reliable transportation, and support the efficient movement of people and goods through environmentally sustainable practices. The projects were developed to independently address several transportation challenges related to safety and mobility in the city. Ultimately, the Smart Columbus Program was redesigned to integrate the different project elements into a holistic solution that was purposely designed and deployed to demonstrate how an intelligent transportation system, focused on equitable access to transportation, empowers all residents to live their best lives.

The Smart Columbus Program began as a portfolio of 15 projects, was reduced to nine projects in 2017, and ended as eight projects in 2021. These eight projects are: Smart Columbus Operating System, Connected Vehicle Environment, Multimodal Trip Planning Application, Mobility Assistance for People with Cognitive Disabilities, Prenatal Trip Assistance, Smart Mobility Hubs, Event Parking Management, and two Connected Electric Autonomous Vehicle (automated shuttle) demonstrations.

This report describes the evolution of the program from award to completion, describing the challenges and circumstances around the portfolio revisions. The report also satisfies USDOT's goals and expectations for the Final Report as outlined in the City's Cooperative Agreement by providing the items below:

- Program management and delivery activities, including the deployment and operational costs of both the program and each individual project
- Performance measurement results
- Challenges, lessons learned, and recommendations
- How the program met the expectations of the City and USDOT regarding:
  - Improvements to safety, mobility, sustainability, access to opportunity, economic vitality and/or reduction in environmental impact
  - Deployment of projects and strategies consistent with the USDOT 12 smart cities vision elements
- Project summaries for each of the eight projects, including a project overview, deployment summary (including systems engineering process applied), project evolution, and project-specific conclusions, lessons learned and recommendations.

It is hoped that others find this report useful in implementing their own smart city programs.

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Executive Summary

ES-1. THE CHALLENGE

The U.S. Department of Transportation's (USDOT) Smart City Challenge (SCC) was created in 2015 to demonstrate and evaluate a holistic approach to using new technologies to improve surface transportation performance within a midsized city, and integrating this approach with other smart city domains such as public services, health, safety and energy. Seventy-eight cities applied for the SCC funding, with seven cities selected as finalists. After a nine-month process, USDOT chose Columbus, Ohio, as the SCC winner in June 2016, with the Cooperative Agreement signed in August 2016.

In the application the City of Columbus described managing aging infrastructure while striving to provide an improved quality of life for a growing population. Every family in every neighborhood should be able to share in the Columbus success story, but they do not.

The City sought to create opportunities for economic development and job creation through the SCC, using transportation improvements to improve mobility and provide ladders of opportunity for residents to better access jobs, fresh food, services, education, health care and recreation. By implementing the Smart Columbus Program, the City began empowering residents to live their best lives through the application of responsive, innovative and safe emerging technologies.

ES-1.1. Empowering Residents to Live Their Best Lives

Throughout his leadership at the City of Columbus, Mayor Andrew J. Ginther has said that "mobility is the great equalizer of the 21st century." If the program outcomes and USDOT Smart City Vision Elements were the technical roadmap of what the City hoped to achieve, Mayor Ginther's vision relates these outcomes and elements to the users: the residents of Columbus.

Figure ES. 1: Columbus Mayor Andrew Ginther

Source: City of Columbus

While connected, autonomous, shared and electric technologies are exciting technical advancements, many cities grapple with how to adopt them within legacy infrastructures. Mayor Ginther's vision to harness these technologies to make the City more equitable and accessible made Columbus stand out in the SCC and the industry, and gave the Smart Columbus Program team its guiding principle. Because without access to modern, integrated transportation options, residents in central Ohio cannot live their best lives.

The City proposed a concentration of demonstrations in its Linden neighborhood because the future of Columbus – and cities like it nationwide – depends on vibrant, thriving neighborhoods. Opportunity neighborhoods such as Linden (that is, lower income and underserved communities) exist throughout the United States and share many of the same challenges. By deploying smart technology solutions in Linden, the City sought to demonstrate how next generation transportation technologies can address some of the damage from decades of redlining, disinvestment, and isolation caused by interstate construction. The program aimed to do that by collaborating directly with the people who reside in Columbus' neighborhoods. Participation was key to success, and Linden residents were ready to work alongside City staff to show how mobility innovations can be deployed in an equitable way, so other neighborhoods across the United States that look like Linden could benefit in the future. Snapshots of resident impact are presented throughout this report to illustrate how these projects delivered on this proposal.

ES-1.2. A Springboard to Innovation

Along with the $40 million awarded via the USDOT Cooperative Agreement, the City also received a $10 million Paul G. Allen Family Foundation grant. With these efforts managed by the City, The Columbus Partnership also initiated the private-sector Acceleration Fund, which began with $90 million and has grown to over $700 million. These three efforts served collectively as a springboard to an innovation initiative within Columbus and the region. The Smart Columbus Program Management Office (PMO) led the USDOT and Paul G. Allen Family Foundation efforts, while The Columbus Partnership coordinates the Acceleration Fund.

The USDOT SCC project portfolio was part of a group of inspired and invigorated community initiatives that explored what's next in urban mobility and technology. With the SCC now complete, and other efforts underway by the City, Central Ohio Transit Authority (COTA), DriveOhio, The Columbus Partnership, the Mid-Ohio Regional Planning Commission (MORPC), regional leaders continue to embrace new ideas and innovative solutions. Community leaders have rallied around Columbus' emergence as a smart city. Policymakers are inspired to generate further change, advance new collaborative initiatives, and support transformative efforts like LinkUS, which was under development before Smart Columbus.

Throughout the regional mobility ecosystem, the spirit of collaboration that fueled the innovation behind Smart Columbus continues. Some projects build upon the infrastructure assets and knowledge the SCC projects created; other partnerships created new programs, introduced new solutions and promoted adoption of new mobility technologies. This summary concludes with a glimpse at these exciting activities.

ES-1.3. Demonstrating Success

Program successes include Ohio's first automated vehicle (AV) deployment on public streets, a multimodal transportation planning app that has been downloaded over 1,000 times, improvements to a parking management app that has been downloaded over 30,000 times, and an operating system that is built largely on open-source software, and is easy and cost-effective for other cities to implement. The City's experience also resulted in a collection of technical information and lessons learned for other regions interested in implementing smart cities projects. Importantly, five of the eight projects are continuing after the SCC funding ends, proving both the value of these projects to residents and their efficiencies for local government.

Section ES-5 summarizes the impacts related to USDOT's Smart City Vision, the City's performance measurement outcomes, and the City-specific impacts to residents and the local economy.

ES-2. PROGRAM OVERVIEW

The City's SCC application outlined 15 projects grouped according to district (downtown, residential, commercial and logistics) and by theme (Enabling Technologies, Enhanced Human Services and Emerging Technologies). Enabling Technologies leverage today's technology in new and innovative ways to greatly enhance the safety and mobility of transportation infrastructure. Enhanced Human Services meet human needs through the application of technology that focuses on prevention as well as remediation of problems to improve the overall quality of life of users of the technology-based solutions. Emerging Technologies represent technologies that are in development or will be developed over the next five to 10 years will substantially alter the business and social environment.

While the original framework was envisioned as a cohesive program, it did not define connections and coordination points during the projects' development and design. As the first year concluded, the Smart Columbus PMO worked to streamline the original portfolio and bring more clarity to the program and schedule.

After reevaluating the 15 proposed projects in the context of USDOT's expected outcomes, the City's original goals, and end-user and stakeholder feedback gathered throughout the program's first year, the PMO removed some projects, consolidated others, and added one. The reduced portfolio of projects preserved the program's focus on Columbus' communities, keeping in place the three overarching themes developed since the SCC award.

Of the nine projects that remained after the first year, one – Truck Platooning – was removed in 2019 because the systems engineering process identified user needs that existing technology could not meet, and the project partner could not support a 12-month demonstration.

The Multimodal Trip Planning Application and Common Payment System was modified in 2020 to remove the Common Payment System component. The COVID-19 pandemic exacerbated this project's existing challenges, which included the inability to finalize participation and terms-of-ownership agreements between mobility providers and COTA, the designated owner of the technology solution.

ES-2.1. The Portfolio

Figure ES. 2 presents the final project portfolio: seven projects that fall under the three original themes, and the Smart Columbus Operating System project – which acts as the point of integration (and which the City anticipates it will continue to maintain) – collects, manages and produces the data needed to operate all current and future smart city projects.

The Smart Columbus Program demonstrated the following eight projects:

- **Smart Columbus Operating System (SCOS)** – The SCOS is a platform designed for big data, analytics, and complex data exchange. It collects, manages and produces over 2,000 datasets, including data from each of the Smart Columbus projects, and provides multiuser access to aggregate, fuse and consume data.
- **Connected Vehicle Environment (CVE)** – CVE deployed connected vehicle technology at 85 intersections and in over 1,000 vehicles across four City corridors. The CV devices enabled vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communication, supporting safety and mobility applications that provide alerts to drivers, coordinate signal priority and preemption at intersections for priority vehicles, and provide data to the City and COTA.
- **Multimodal Trip Planning Application (MMTPA)** – MMTPA project created a website and smartphone app called Pivot, which allows travelers to request and view multiple-trip itineraries and reserve transportation options such as ride-hailing services and bike- and scooter-sharing.
- **Mobility Assistance for People with Cognitive Disabilities (MAPCD)** – MAPCD demonstrated an innovative smartphone app – WayFinder by AbleLink – for older adults and people with cognitive disabilities to facilitate independent travel via the fixed-route bus system. The app features highly accurate, turn-by-turn navigation that is sufficiently intuitive for users who have cognitive disabilities.

- **Prenatal Trip Assistance (PTA)** – PTA created a call center, and smartphone app and website (called Rides4Baby) for use by pregnant individuals to schedule flexible, reliable, two-way transportation to medical-related services. The project delivered non-emergency medical transportation (NEMT) services through Medicaid Managed Care Organizations (MCOs).
- **Smart Mobility Hubs (SMH)** – SMH consolidated transportation resources and offered access to comprehensive trip-planning tools at six designated locations. These hubs are primarily located adjacent to existing transit center facilities and provide physical space for the consolidation of services such as ride-hailing and bike-, scooter- and car-sharing. Interactive kiosks and public Wi-Fi allow the traveler to view real-time travel information and book multimodal trips via the Pivot app.
- **Event Parking Management (EPM)** – EPM expanded the features of the City's ParkColumbus app and developed a website to integrate parking information from City-owned parking meters and multiple parking facilities into a single availability and reservation services solution. This allows travelers to search for and reserve parking in advance or on the go. More direct routing of travelers during large events is expected to reduce congestion during those times. The solution also identifies the current projected on-street parking availability near users' target destinations using predictive analytics.
- **Connected Electric Autonomous Vehicles (CEAV)** – CEAV deployed autonomous shuttles that operated in mixed traffic, interacting with other vehicles, bicyclists and pedestrians. The project conducted two demonstrations: one in Downtown Columbus and one in the Linden community.

ES-2.2. Outcomes for Performance Measurement

The Smart Columbus Program identified the following six outcomes, or broad statements about positive societal impacts, which connect the eight projects to the SCC's original intent (see **Figure ES. 2**). These outcomes represent the many potential indicators that make a city a great place to live, work or visit, and they were at the forefront of each project's development and demonstration.

1. **Safety**

   Three Safety objectives related to increasing drivers' awareness of signals and other vehicles in the corridors were evaluated for the CVE project.

2. **Mobility**

   - Eight Mobility objectives were evaluated at the program level and for the CVE, MMTPA, SMH, MAPCD, PTA and CEAV projects.
   - The Mobility objectives focused on how enhancing mobility applies to all transportation modes, and how making these modes more accessible and usable with real-time traveler information and innovative technologies impacts individual mobility.

3. **Opportunity**

   - Five Opportunity objectives were evaluated at the program level and for the MMTPA, MAPCD, PTA, CEAV projects.
   - Opportunity objectives focused on improved access to transportation options for Columbus residents, including those in underserved communities, by connecting them to employment, education, health care and other services while increasing transportation network use by bringing together available services and users.

4. **Environment**
    - One Environment objective was evaluated at the program level, with the CVE, MMTPA and EPM projects contributing (and assessed as a group).
    - The Environment objective to reduce transportation's negative impacts on the environment by implementing advanced technologies and policies that support a more sustainable transportation system.
5. **Agency Efficiency**
    - Five Agency Efficiency objectives were originally applied to the SCOS and MAPCD projects; however, the MAPCD objectives were not evaluated due to a change in participant recruiting.
    - The Agency Efficiency objectives focused on improving agencies' ability to provide services to residents through advanced technologies that enabled easier access to real-time data, streamlined internal processes, and improved information-sharing.
6. **Customer Satisfaction**
    - Seven Customer Satisfaction objectives were evaluated for the SCOS, MMTPA, SMH, PTA, EPM, and CEAV projects.
    - The Customer Satisfaction objectives focused on providing services embraced by the community and improving the user experience of transportation and community services through integrated data exchange and advanced technologies.

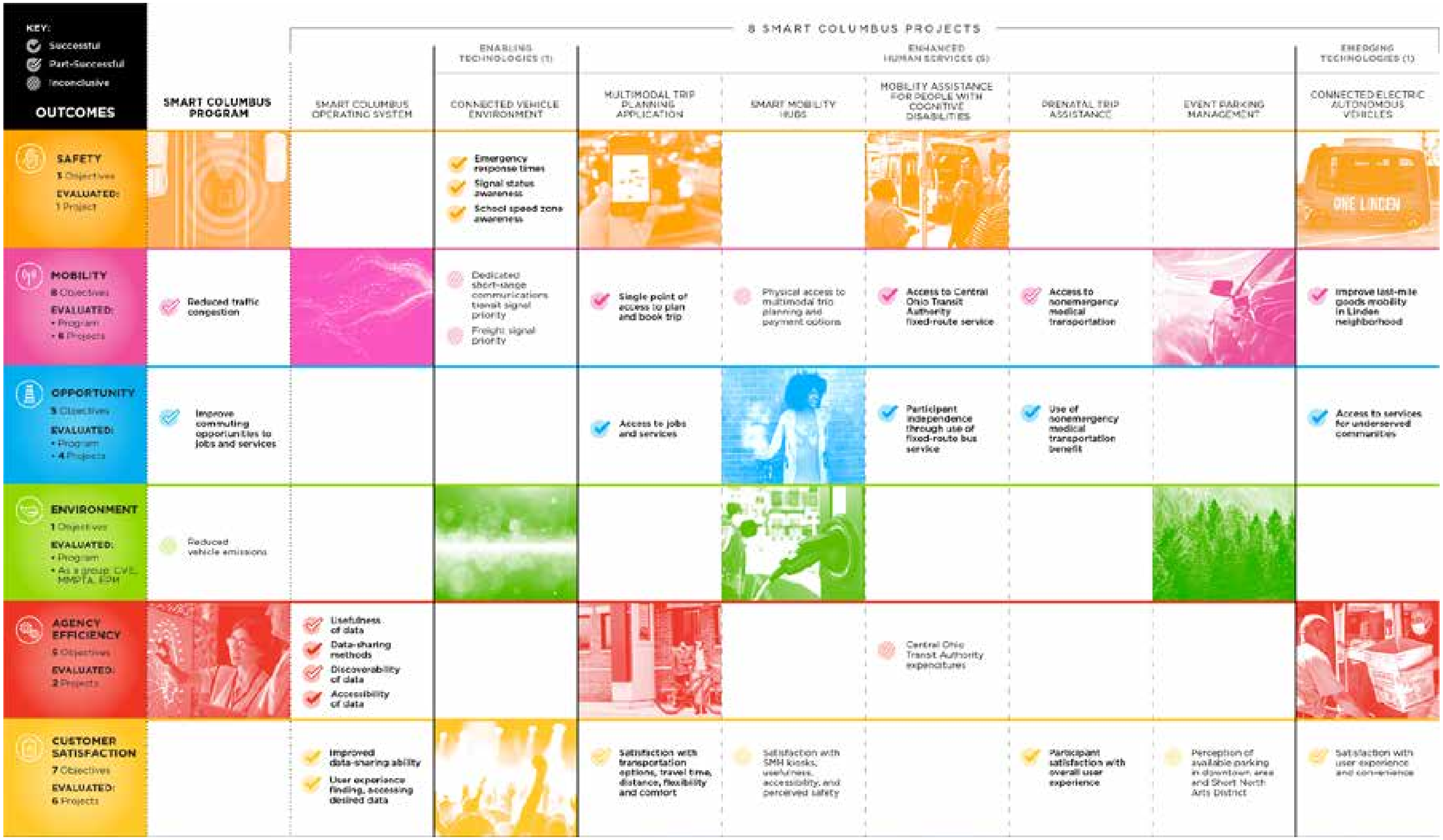


Figure ES. 2: Smart Columbus Program and Outcomes

Source: City of Columbus

ES-2.3. Deployment Areas

Like most midsized cities in the United States, Columbus is divided into several neighborhoods, commercial districts, and other geographic zones connected by highways, transit, people and culture. While the Smart Columbus Program deployed some projects within specific areas, many projects were deployed citywide. **Figure ES. 3** shows the following geographic deployment areas of the projects:

- **CVE** – The deployment corridors include Cleveland Avenue, High Street, Morse Road and Alum Creek Drive.
- **MMTPA and MAPCD** – As one of the key mobility providers, the map highlights COTA's service area.
- **PTA** – Franklin County was the recruiting area for the project, which focused on Linden and other zip codes with high rates of poor birth outcomes.
- **SMH** – Most hub locations are along COTA's Cleveland Avenue bus rapid transit (BRT) route, with one in Easton.
- **EPM** – The map highlights the Downtown and Short North areas of Columbus because the ParkColumbus app focuses on parking providers in these areas and travel to and around them.
- **CEAV** – The map shows both the Smart Circuit and Linden LEAP routes and stations, and the passenger and food pantry routes for the Linden service.

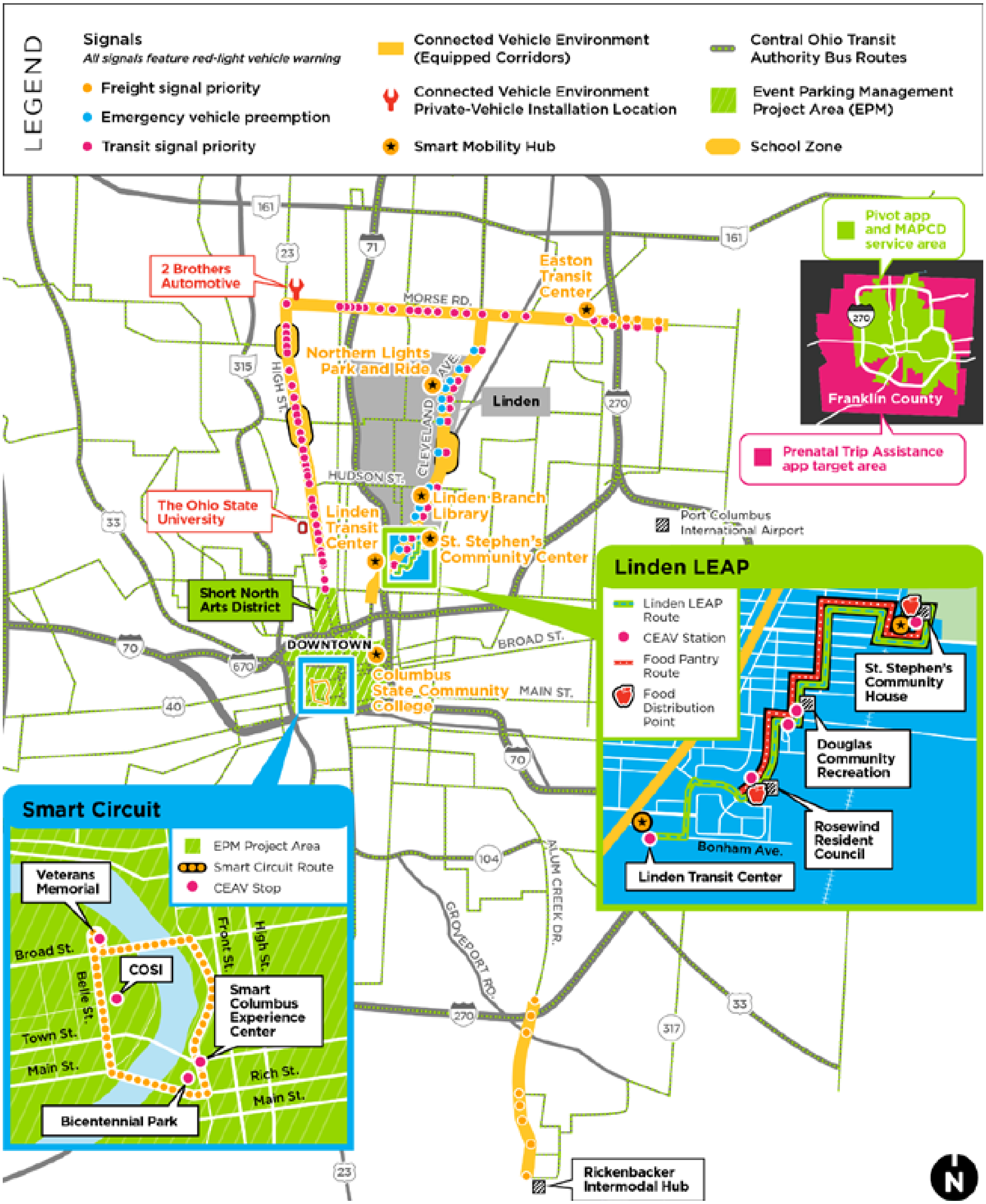


Figure ES. 3: Deployment Map

Source: City of Columbus

ES-3. MANAGEMENT AND DELIVERY

The delivery of the USDOT SCC demonstration relied on several major program management pillars. The City used the structure outlined by USDOT in the Cooperative Agreement to deliver the program, while managing the systems engineering tasks at the individual project level. Program-level items included program management (including budget), performance measurement, data management and privacy, safety management and assurance (including the Institutional Review Board, IRB), communications and outreach, and reporting (including this final report, as well as quarterly reports to USDOT). Overall, this structure provided consistent guidance to the project teams, and a more cohesive and integrated program portfolio while satisfying all Cooperative Agreement requirements and deliverables.

More details on these elements are contained in the Final Report Chapter 3, while this summary highlights the final budget, a timeline of the program's major milestones, lessons learned, challenges and how the deployment approach sought to mitigate them.

ES-3.1. Budget Summary

Over the course of the program, the budget was revised multiple times as changes were made to the individual projects, including those that were removed such as Truck Platooning and CPS. What was initially scoped as approximately $59 million concluded at approximately $55 million, divided among the federal award (nearly $40 million) and four cost-share partners (providing over $15 million). Costs of the eight individual projects represented nearly $37 million dollars of the budget, as shown in **Figure ES. 4,** which provides the costs by project and category as of March 2021. Unspent funds will be allocated to the final two months of the program (April-May 2021), with the balance returned to the program sponsor.

Not included in the charts below is the value of the support provided by 13 additional project partners or key leveraged partners. These key leveraged partners provided approximately $37.5 million in support of the demonstration, as specified in the Cooperative Agreement. These contributions ranged from key concept contributions like Sidewalk Labs PTA user needs research, to foundational structural support for the SCOS from Amazon Web Services (AWS) (hosting) and Battelle (data curation).

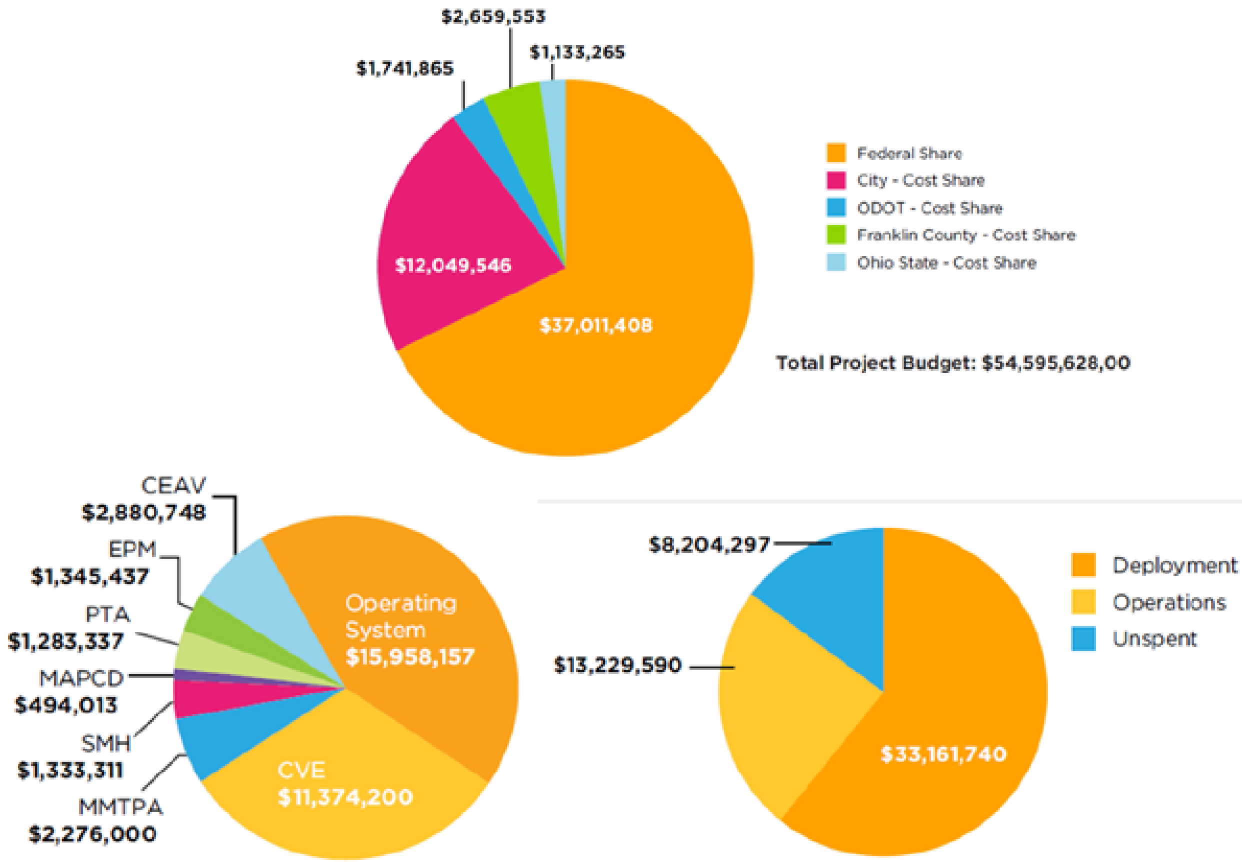


Figure ES. 4: Final Program Budget

Source: City of Columbus

ES-3.2. Timeline and Milestones

The first year of the program was spent developing a comprehensive approach for program management and systems engineering, anchored by a structured stakeholder engagement process. Highlights from the first year included work associated with establishing communications, beginning the systems engineering process, and defining the integrated data exchange, later known as the Smart Columbus Operating System. The demonstration also encountered several challenges its first year, which encouraged further program changes and adaptations, and helped the City identify where to chart a better path forward. Intra-program communications – among and between the projects and the SCOS at its core – were front and center as a lesson learned for continued enhancement.

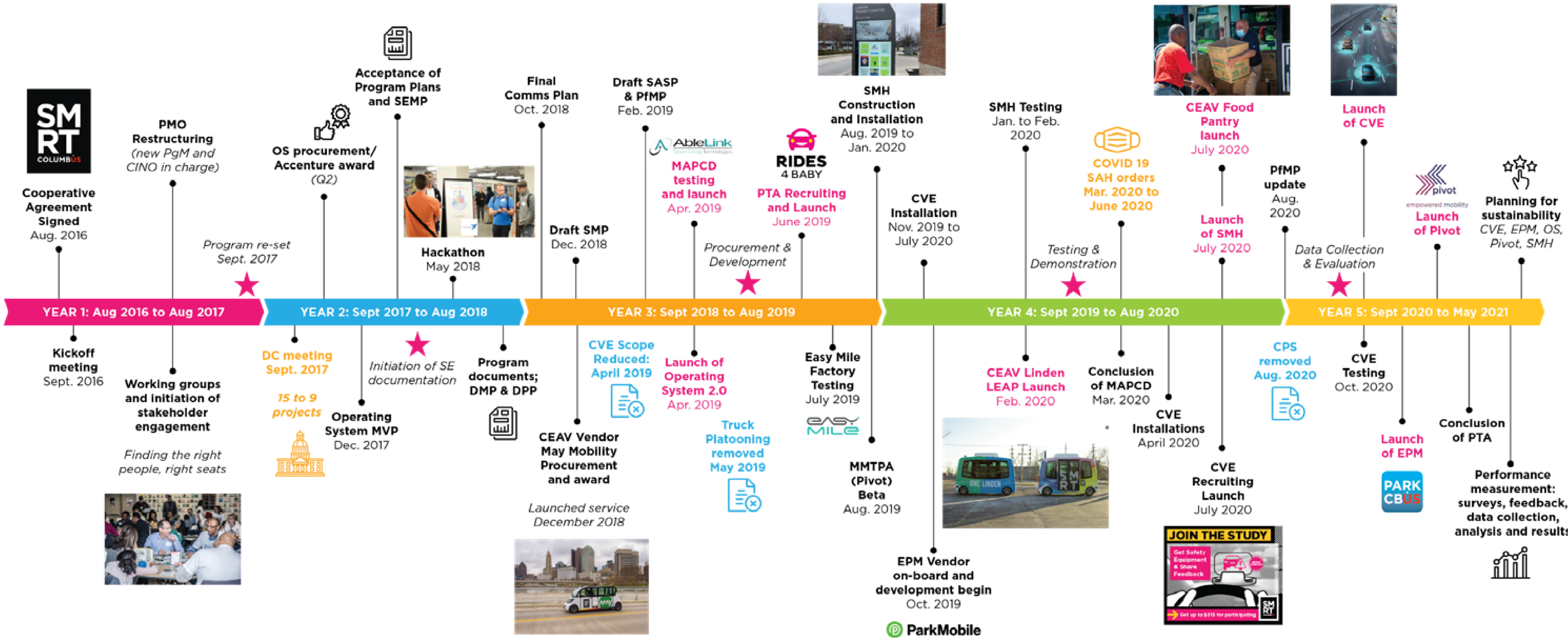
As a result of these challenges, during the second year, the team finalized the program management structure and the portfolio of projects. Key milestones in these first two years were the consolidation and reorganization of the portfolio (September 2017), the launch of the data environment that would become the SCOS (December 2017), and the opening of the Smart Columbus Experience Center (June 2018), which gave the Smart Columbus Program a headquarters co-located with partners, as well as an additional platform for community engagement.

The third year focused on procurement and launching three projects, including the first CEAV demonstration (Smart Circuit) on the Scioto Mile in December 2018. Recruiting for the MAPCD project began in February 2019. Recruiting for the PTA project began in June 2019.

The fourth year focused on launching all remaining projects, while navigating the complexities and challenges of deploying mobility solutions in the pandemic environment.

The fifth and final year (from September 2020 to May 2021) focused on data collection, evaluation and planning for the continuation of several projects including the SCOS, CVE, EPM and MMTPA.

Figure ES. 5 captures highlights of the program.



CEAV = Connected, Electric, Autonomous Vehicle
CINO = Chief Innovation Officer
CPS = Common Payment System
CVE = Connected Vehicle Environment
DMP = Data Management Plan
DPP = Data Privacy Plan
EPM = Event Parking Management
LEAP = Linden Empowers All People
MAPCD = Mobility Assistance for People with Cognitive Disabilities
MMTPA = Multimodal Trip Planning Application
MVP = Minimal Viable Product
OS = operating System
PfMP = Performance Measurement Plan
PgM = Program Manager
PMO = Program Management Office
PTA = Prenatal Trip Assistance
SAH = Stay-at-home
SASP = System Architecture and Standards Plan
SE = Systems Engineering
SEMP = Systems Engineering Management Program
SMH = Smart Mobility Hubs
SMP = Safety Management Plan

Figure ES. 5: Smart Columbus Program Highlights

Source: City of Columbus

ES-3.3. Challenges

Throughout the five-year program, there were successes and failures, and many lessons learned. The original 15 projects were trimmed and combined to a more manageable eight projects. Some projects were removed when it was discovered that there were other solutions being developed that did not require a "smart cities" approach. Others were lost due to difficulties in developing legal or other agreements within the project timeframe – not surprising when dealing with projects that had few if any precedents. The scope of other projects such as CVE changed because of the readiness of the technology, and the need to ensure that project implementation goals were achievable given the available time and resources. Almost all projects were changed in some way when the COVID pandemic hit and completely altered the world's transportation landscape. The full report details the complete set of challenges across the program and for each project, including the impact of the challenge and the mitigation that was applied.

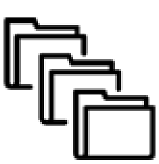
LESSONS LEARNED

- **Adapting from application to reality: Cities need flexibility in moving plans forward when working with developing technologies**
- **Managing and incorporating partner expectations: They do not always align with user needs or program policies**
- **Identifying and solidifying the resources: This impacts the ability engage quickly and start strong**
- **Applying traditional systems engineering to emerging technology projects requires flexibility and adaptation**
- **Unanticipated events will always be encountered, and the following two stand out for Smart Columbus:**
  - The Federal Communications Commission Notice of Proposed Rulemaking regarding the 5.9GHz safety spectrum, which delayed implementation of the CVE project
  - The COVID-19 pandemic, which affected all the projects: their implementation, their usage, and even their performance assessments

ES-3.4. Deployment Approach

Throughout these challenges, the City relied on comprehensive stakeholder collaboration to ensure that we remained true to our founding concept of focusing on the end users – the residents of Columbus. From the beginning, the City worked with the following guiding principles when designing, deploying, and operating the Smart Columbus Program. These principles were instrumental in helping the PMO identify and manage the many challenges that emerged over the nearly five-year program across the eight projects.

Human-Centered – Intended-use cases and end-user engagement such as surveys, interviews, working groups, beta testing and the participation of community liaisons, guided every technology deployment. This enabled the teams to solve real-world community challenges. For example, personal preferences stated within the Pivot app informed route design, and the mobility needs of specific individuals guided design of the PTA and MAPCD projects, with PTA providing NEMT for pregnant individuals, and MAPCD empowering individuals with cognitive disabilities to travel independently via public transit.



Replicable – The Smart Columbus Program established governance and standards for the projects, so that other cities could replicate the technology solutions. For example, the code developed for the SCOS – a scalable data-management platform designed to serve the needs of public agencies, researchers, entrepreneurs and the private sector – is open source and accessible on GitHub.com. Similarly, MMTPA uses open, free and proven software (Open Trip Planner) that other cities such as Portland, Oregon, have already implemented.

Collaborative – Partners from throughout the community, including COTA, DriveOhio, the MORPC, The Ohio State University (OSU) and companies from the region's private sector helped to advise the development, implementation and sustainment of the projects within the portfolio. Coordination with efforts and projects taking place elsewhere in the region, or through other funding sources, were leveraged and brought together for the benefit of all stakeholders and projects. As an example, the CVE project continuously coordinated with DriveOhio and the 33 Smart Mobility Corridor project, which allowed the City to use existing software components that DriveOhio had already procured.

Holistic – It is important when advancing multiple technology and mobility projects, especially those integrating multiple modes, to use a holistic technology approach with common goals, providers, and solutions that can potentially contribute to multiple projects. Sometimes, this meant partnerships did not materialize as intended. The consistent coordination with the efforts and projects taking place elsewhere in the City, and through other funding sources, did result in successfully leveraging certain partnerships for the benefit of all stakeholders and projects. For example, the SMH leveraged both a grant from American Electric Power (AEP) for electric vehicle (EV) equipment and an existing agreement between Experience Columbus and Orange Barrel Media to install IKE Smart City kiosks free of charge.

Agile – The tenets of Agile systems engineering – small, incremental ("thin slice") delivery and failing fast to allow for fast improvement – were crucial in managing the inherent uncertainties surrounding emerging technology. It enabled the Program Management Office to dare greatly, learn from failure, and understand when to move forward and when to call it quits. Applying this approach was key in managing risk and accommodating changes, while still completing documentation for user needs, system requirements and testing for all projects. This experience has left the City better equipped to take risks in the future, ready to embrace technology, deploy these innovative solutions and integrate them into the City's infrastructure and operations.

ES-4. THE SMART COLUMBUS PROJECTS

The Smart Columbus deployments were not "demonstrations of tech for tech's sake." They delivered quantifiable outcomes that sought to serve the community. While the COVID-19 pandemic presented challenges to implementing the final portfolio of eight projects, these deployments still delivered measurable progress against all of Columbus' six intended outcomes (shown in **Figure ES. 2**).

Behind the safety, mobility and customer satisfaction outcomes, are the stories of Columbus residents who benefitted from the Smart Columbus projects firsthand. These residents experienced the potential that intelligent transportation systems hold through an easier way to get to work or entertainment, through access to food services that were needed during the pandemic, through investments in their Columbus-based tech or automotive businesses, or through hands-on job skills training. Stories of how the Smart Columbus projects empowered residents are presented throughout this report, with highlights shared in each project's chapter.

What follows is a snapshot of each of the eight projects. These summaries describe the final components as they were demonstrated and evaluated, with examples of the personal impact the project had on Columbus residents. Each project's chapter describes in detail the specific challenges that were encountered and their impact on the project in terms of size and scope.

ES-4.1. The Smart Columbus Operating System

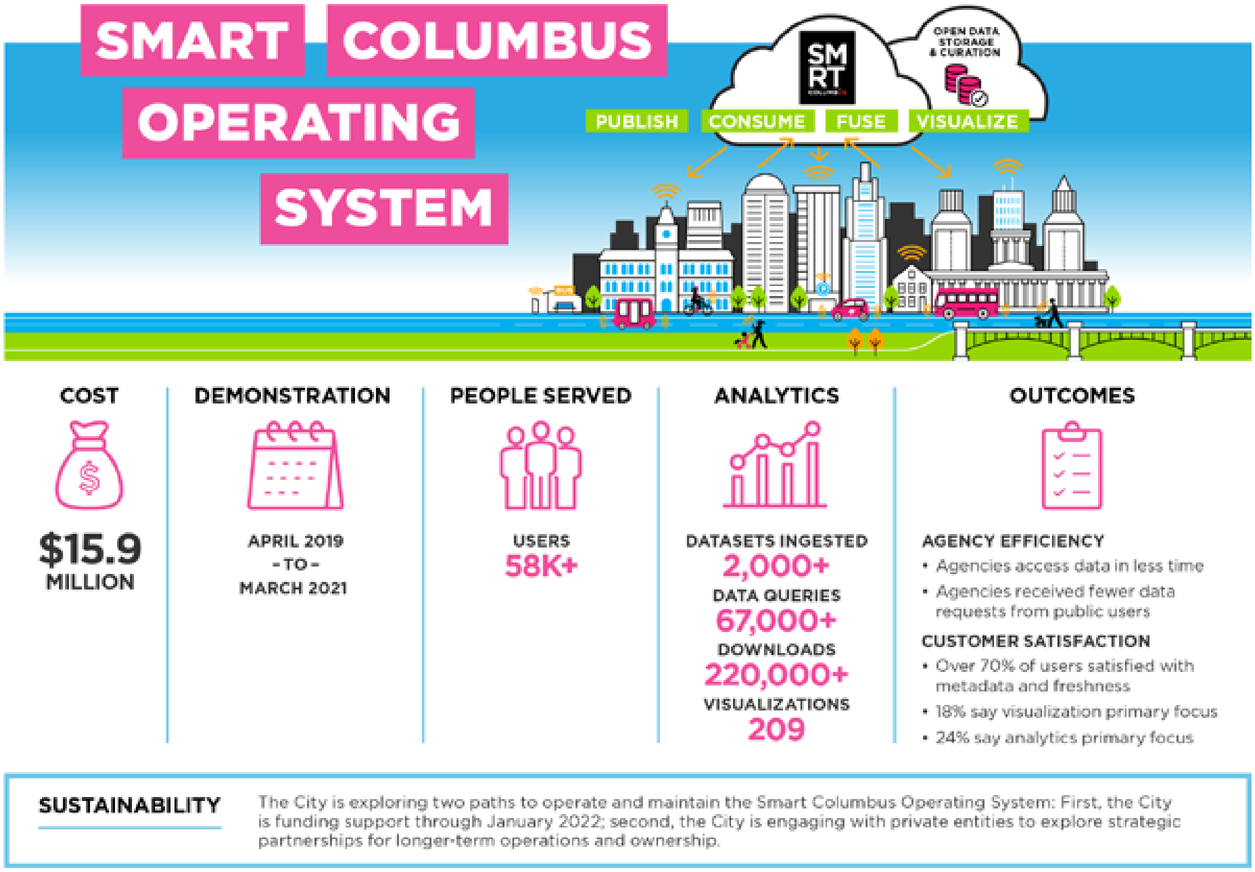


Figure ES. 6: Smart Columbus Operating System at a Glance

Source: City of Columbus

Data is the heartbeat of a smart city, but Columbus – and cities like it nationwide – lacked a centralized data delivery platform. The SCOS is a cloud-agnostic, open-source data platform that houses all the Smart Columbus Program performance indicator data and uniquely generated project data, and it integrates all the program's projects into a central data platform. It provides the key functionality to develop and explore new concepts in data-driven transportation infrastructure by sending, receiving and visualizing real-time data from public and private organizations. The goal of this project was to create a replicable and sustainable data platform that enables cities, researchers, nonprofits, and businesses to better make decisions and solve problems.

The SCOS features a first-of-its-kind visual data ingestion interface for internal and public use, allowing the input and integration of data from a wide variety of sources. It provides streaming data services, ingesting the real-time project data from the CVE and program partners such as COTA. Other features include browser-based data querying and visualization tools, and machine learning and hosting (specifically the EPM project's parking predictive availability model). The SCOS is proving its value outside of transportation as well. The City's Division of Infrastructure Management used it to host their Employee and Work Order Allocation Dashboard, which was a key deliverable in improving agency efficiency.

Operating System Features and Functions Put Columbus a Step Ahead

A major hurdle for cities and municipalities to adopting more smart city technologies is the ability to process and manage the incredible amount of data generated by the Internet of things like sensors. The Connected Vehicle Environment showed the Smart Columbus Operating System has the capability to not only store, but process and manage 65 million new records each day. This functionality puts the City of Columbus ahead of many other US cities and we're excited to see how that functionality will move the region forward in the future.

Aaron Schill, Director, Data & Mapping,
Mid-Ohio Regional Planning Commission

The SCOS is built upon the principle of microservices architecture, where a series of processes communicates over a network to fulfill the goal of storing and retrieving data. All SCOS components had to meet the following criteria: open source, widely used in the development community, and well-documented support for implementation and maintenance. This ensures that Columbus, and any future city that implements a similar system, can easily find the development resources and support it needs. While open technologies are less common in the public sector, leading technologists in innovative organizations often favor them. This approach brought these innovative engineering capabilities to the SCOS and ensured that the SCOS could be migrated across technology platforms without vendor lock-in, reducing licensing costs for software, and providing public access to the SCOS technology.

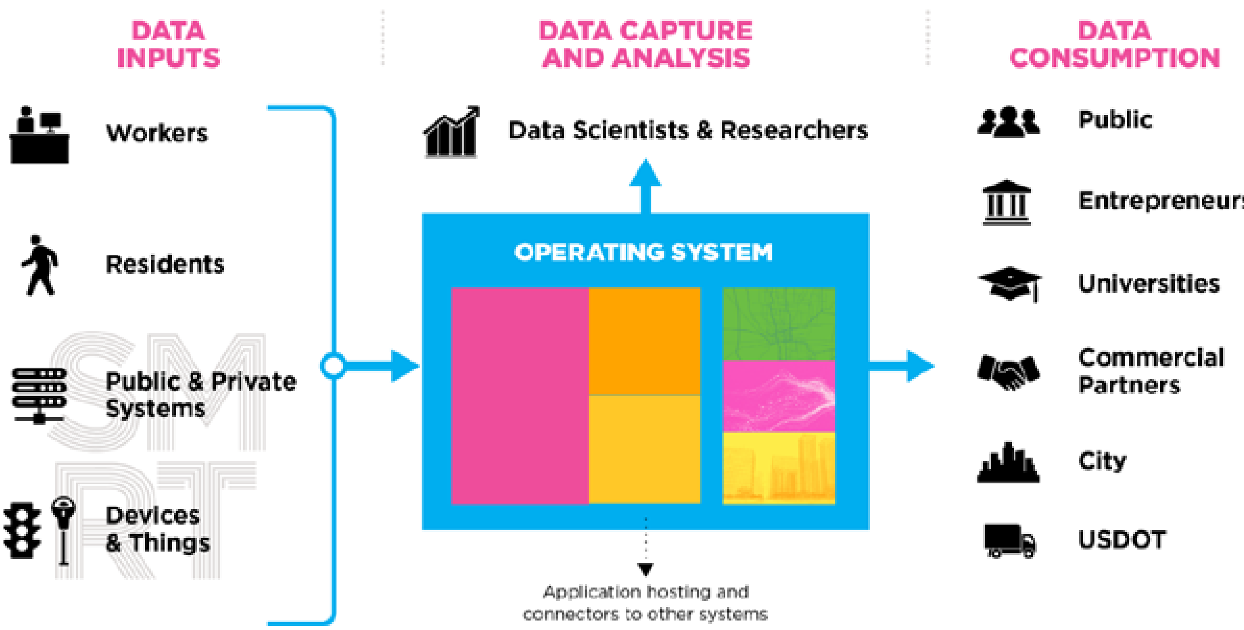


Figure ES. 7: Smart Columbus Operating System Overview

Source: City of Columbus

ES-4.1.1. KEY FINDINGS

- **Implementation approach** – The SCOS was the only project to be completely developed using an Agile systems engineering methodology (explained in Chapter 2), and it reflects constant and consistent engagement from stakeholders and the user community. This stakeholder engagement benefitted the project by increasing awareness of the City's open data efforts, engaging more individuals and organizations with the SCOS, and encouraging use and feedback of the system features. Some notable examples include:
  - Two Hackathons in 2018 and 2019 promoted by The Columbus Partnership.
  - Engagement with data enthusiast meetups and conferences including the Smart Columbus Open Data Enthusiast and Code for America groups, which hosted monthly meetups at the Smart Columbus Experience Center to engage with the SCOS delivery and development teams and PMO.
  - lose contact with five Technical Working Group segments, meeting monthly in person with frequent followup and collaboration via email newsletters and public Slack channels. All these working groups sought to develop datasets, user stories, data management and privacy policies, and ideas related to the development and sustainability to the SCOS, specifically.
- **The SCOS demonstrates the criticality and priority of privacy and security to both the program and the City** – The protection of personally identifiable information (PII) was identified as an early priority in the program, and from that point forward, affected the development of the Data Privacy Plan and the Data Management Plan and their implementation. As a result, the SCOS does not collect or store any PII, which minimizes privacy and security risks, reducing requirements in product and operations, and strengthening public trust.
- **The SCOS was a project that successfully leveraged partnership opportunities** – Amazon provided hosting services throughout the Cooperative Agreement, and Battelle provided data curation services for a majority of the program.
- **The replicability and scalability of the SCOS has been demonstrated** – The SCOS codebase does not rely on the architecture of any one cloud provider and has been implemented successfully on the three major providers – AWS, Azure and Google. Likewise, demonstrations have validated that with the available documentation and guidance provided by the development team on Github, an instance of the SCOS can be implemented in as little as two to four weeks by two developers.[1]

The City is exploring two paths for near-term support to operate and maintain the SCOS: simply paying to support the SCOS through January 2022; and potentially engaging with private entities to explore strategic partnerships.

1 *Source: Accenture*

ES-4.2. Connected Vehicle Environment

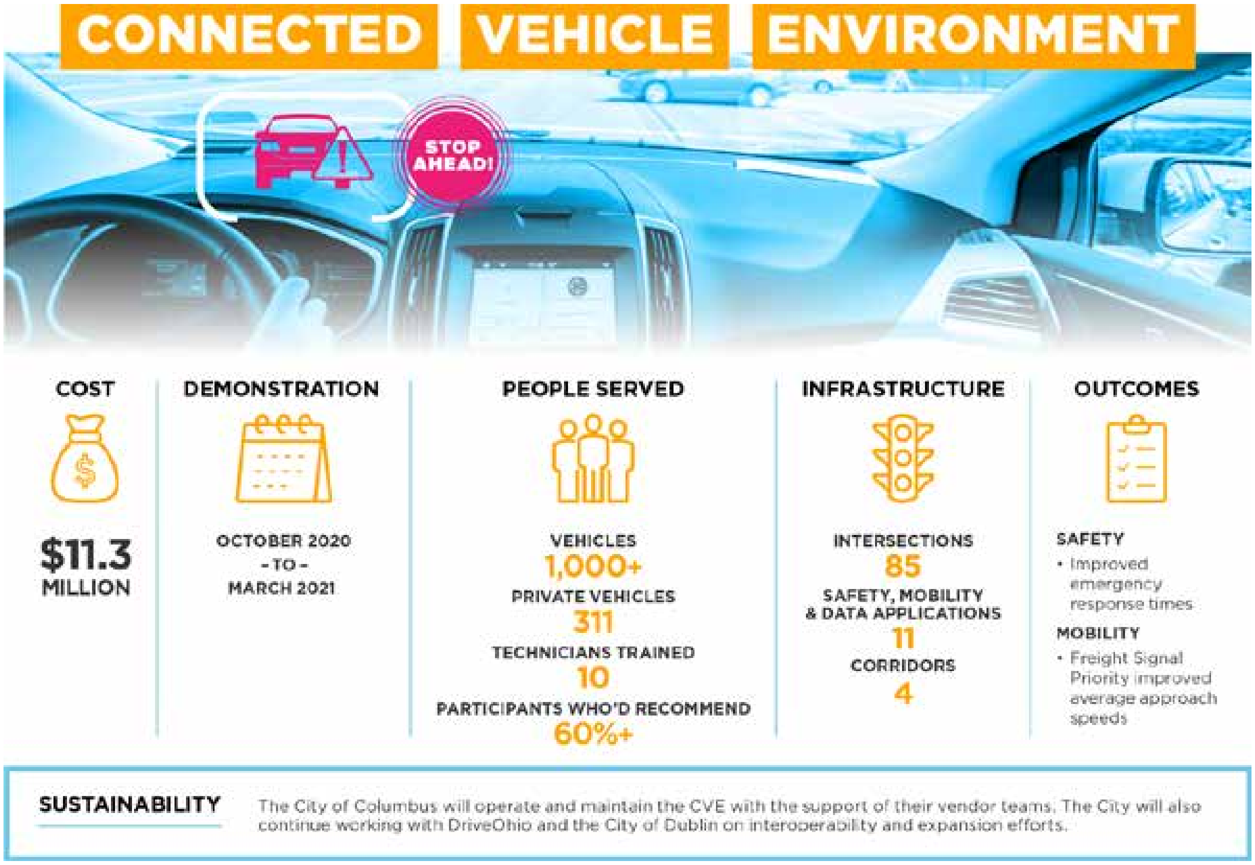


Figure ES. 8: Connected Vehicle Environment at a Glance

Source: City of Columbus

The City of Columbus created an environment powered by connected infrastructure where cars can “talk” to one another to provide safety alerts like blind-spot detection or forward collision warning. Infrastructure can also be alerted about the approach of an emergency vehicle or freight vehicle, and change traffic signals to green. The goal of the CVE project is to improve safety and mobility of Columbus’ residents by reducing car crashes, improving response times of emergency vehicles, improving on-time rates of buses, and providing data to traffic managers.

Grandmother Uses CV Technology to Keep Her and Her Granddaughter Safe on Trips to Dance Class

Tonie lives in Reynoldsburg, an eastern suburb of Columbus, and travels the Connected Vehicle Environment corridor to take her granddaughter to competitive dance lessons daily. She joined the study because she was interested in driver safety technology after experiencing a few costly fender benders. **"I quickly adapted to getting the alerts in my vehicle. There were occasions when it made me aware of things I wouldn't have noticed otherwise. I particularly liked the red light warning alert."** Tonie plans to keep the CV equipment installed in her vehicle and hopes the technology becomes more widely available. **"My granddaughter is always amused when I'm driving her to dance and we get an alert; she laughs. I take that opportunity to talk to her about driver safety, which I hope she takes with her when she becomes driving age."**

Tonie, CVE Study Participant, Reynoldsburg

The CVE project deployed secure, high-speed wireless communication technology and accompanying software applications, both at roadside intersections and in vehicles, to exchange critical situational data between the vehicles (V2V), and between vehicles and infrastructure (V2I). The software applications use data to alert drivers of potential safety issues. The City of Columbus also collaborated with public agencies and private companies to support improved mobility for public safety, transit, and freight operators. Finally, the CVE serves as a source of high-quality data for traffic management, safety analyses, and other transportation-related research purposes.

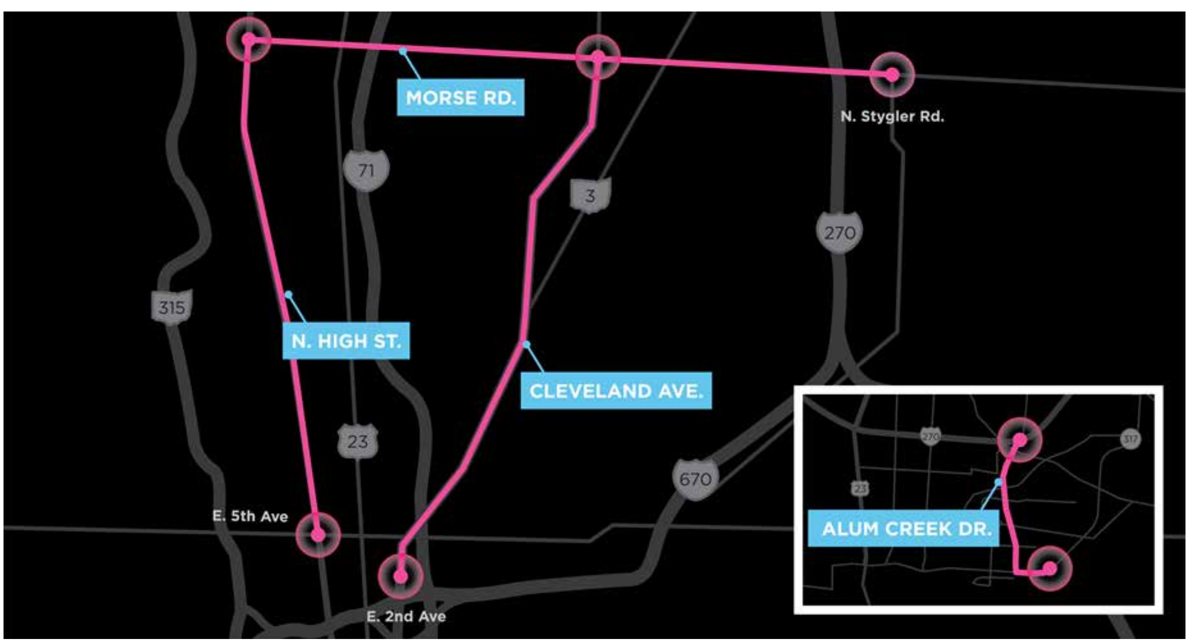


Figure ES. 9: Connected Vehicle Environment Study Area

Source: City of Columbus

The CVE is enabled by a communications network that allows the City to connect the region's signalized intersections using a secure, high-speed fiber network backbone called the Columbus Traffic Signal System. Roadside units (RSUs) were installed in 85 signalized intersections along four distinct corridors to broadcast the current state of a traffic signal or school zone.

Onboard units (OBUs), which receive and report critical warnings from the CVE infrastructure and from other technology-equipped vehicles, were installed in over 1,000 vehicles. A total of 11 connected vehicle (CV) alerts and other applications were deployed in various combinations, depending on vehicle class. Many vehicle installations included a heads-up display, which displayed alerts to drivers for a variety of circumstances. While the alerts on the display are formatted simply, **Figure ES. 10** summarizes the different scenarios addressed by the applications developed for the CVE project**.**

Figure ES. 10: Connected Vehicle Environment Applications

Source: Siemens Mobility

ES-4.2.1. KEY FINDINGS

- The CVE created a rich set of safety and mobility data, sending nearly 1 billion basic safety messages through March 2021. A vehicle transmits a basic safety message (such as vehicle location and speed) at 10 times per second.
- The deployment of RSUs and applications geared toward transportation operators at the City and COTA have expanded Columbus' intelligent infrastructure. This infrastructure increases the traffic-related data collected by the City, and the applications – particularly Vehicle Data for Transportation Operations (VDTO) and Transit Vehicle Interaction Event Recording (TVIER) – demonstrate how stakeholders can integrate this data into their existing operations, creating a more robust data source and identifying potential gaps and areas for improvement. This data enabled a better understanding of traffic management metrics around the City.

- The project engaged local automotive shops for installations, creating a workforce development opportunity beyond the technology demonstration. Working with local auto repair shops, training them on emerging technology, and educating them on the capabilities and benefits also contribute to the overall advancement and acceptance of the technology. CVs will require a workforce trained in the technology for long-term sustainability, and the CVE project tackled this challenge directly.
- Partnership and coordination with DriveOhio were key to the success of the project. DriveOhio's position correction and security credentials were leveraged for deployment, and the CVE project team regularly coordinated with DriveOhio on their deployments in Marysville and Dublin, helping to establish the statewide architecture upon which all CV deployment is expected to follow.

TRAFFIC MANAGEMENT METRICS

- **2,705 hard-braking events**
- **7,637 red-light violation alerts**
- **1,349 alerts to reduce speed in school zone**
- **Transit vehicle V2V interactions:**
  - 13 emergency electronic brake lights
  - 9,208 lane-change warnings
  - 180 intersection movement assists

The City of Columbus will operate and maintain the CVE for at least 15 months following the conclusion of the Cooperative Agreement with the support of their RSU and OBU vendors.

ES-4.3. Multimodal Trip Planning Application

Figure ES. 11: Multimodal Trip Planning Application at a Glance

Source: City of Columbus

Central Ohio residents rely heavily on their own cars to travel, contributing to traffic congestion that will only get worse as the population grows. The MMTPA project's Pivot app makes it easy to find and pay for the best way to get to a destination using more than one mode of transportation, such as bus, bike, scooter, and ride-hail service. The app suggests routes based on preferences such as schedule, budget and preferred transportation options. It is powered by real-time data from mobility partners, optimized by the SCOS. The goal was to improve mobility by reducing traffic and increasing access to jobs, education, and services for all Central Ohio residents.

Essential Worker Uses Pivot for All Transportation Needs

Morgan is a mom of 4 who works in the hospitality industry in the Short North. She owns a vehicle but chooses to take the bus to work because it's easier than finding and paying for parking. **"I used to use Transit but with the real-time bus information, route information, and voice navigation in Pivot, I'm a convert. I even share it with my fellow bus riders so they don't have to guess which bus to take or what stop to get off at."** Pivot also helps with the transportation needs of her whole family. **"One day my daughter got out of practice early. I wasn't able to pick her up but through Pivot I was able to book her a cab ride home."**

Morgan, Essential Worker, Linden

The MMTPA project was designed to allow travelers throughout Columbus and outlying communities to create multimodal trips and pay for services using a single, account-based system linked to different payment media and modes of transportation. The resulting application was branded "Pivot," as Columbus sought to become a facilitator for Mobility as a Service (MaaS) by providing a platform that integrates end-to-end trip planning, booking, electronic ticketing, and payment services across all modes of transportation, public or private. Pivot makes multimodal travel options easily accessible by providing a robust set of transportation and payment options. Multimodal trip options include walking, public transit (COTA and Campus Area Bus Service (CABS)), ridesharing (Gohio Commute), bike-sharing (CoGo), scooters (Bird, Lime), ride-hailing (Yellow Cab, Uber, Lyft) as well as personal bikes and vehicles.

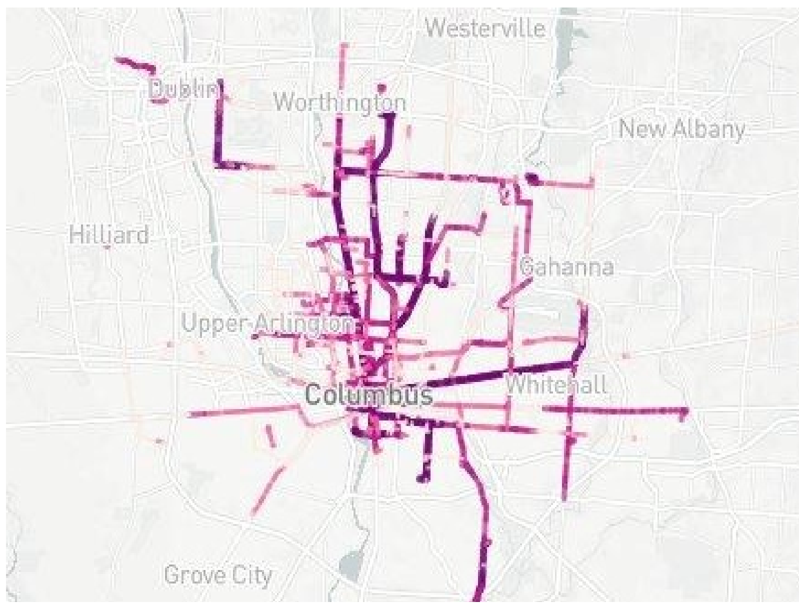


Figure ES. 12: Pivot Trips During Demonstration

Source: City of Columbus

Pivot allows travelers to request and view multiple trip itineraries from within a single app, and book and pay for services through deep linking with various mobility provider apps. Users can compare travel options across modes, and plan and pay for their travel based upon current traffic conditions and availability of services. The Pivot app was conceptualized in 2017 and 2018, followed by the selection of local technology firm ETCH GIS as the vendor to develop the app in 2018. The beta version launched in early 2019, and the time following that beta launch was intended to develop and integrate a common payment system to the application. Challenges and delays related to mobility provider participation and the COVID-19 pandemic resulted in that functionality not being deployed. The public version of Pivot was launched in December 2020.

Figure ES. 13: Pivot Methodology

Source: City of Columbus

The Pivot application uses a foundation of open source, free, and proven technologies. There are no dependencies on subscription services, proprietary code, or commercially licensed data. The platform is made of containerized microservices, which allow for interoperability with the SCOS or another future host environment. The project's custom code is replicable, since it can be entirely redistributed as Massachusetts Institute of Technology-licensed, open-source software. The platform includes a distributed ledger ("blockchain") that offers redundancy, transparency, shared governance, and long-term viability for Columbus and other cities who may decide to deploy the platform to address similar mobility gaps.

What makes Pivot unique:

- Aggregates data from scooter-, bike-, and ride-sharing services, ride-hailing services and public transportation to present customized multimodal (or single mode) trips to the user based on the user's preferences.
- Innovative in the industry by providing a seamless trip plan with mixed-mode travel.
- Open-source platform that can be adapted by other states, cities, and agencies, and flexible enough to change and accommodate the needs of various organizations.
- Neutral, standards-driven multimodal platform.

ES-4.3.1. KEY FINDINGS

- **User adoption is significant and has been steadily growing.** Since the beta version launched, over 3,000 multimodal trips have been taken with Pivot, 447 of those during the demonstration period (from December 2020 through March 31, 2021), with over 1,000 downloads and over 600 registrations. Since September 2019 when trips first began, over 5,000 miles have been travelled by Pivot users, with more than 1,700 of those miles since public launch in December 2020.
- **Low-cost, secure, efficient and resilient options for trip planning are available to cities** – Pivot was developed to be a low-cost solution using integrated, open-source technologies, including: Open Trip Planner, OpenStreetMap, Pelias GeoCoder, and Blockchain Hyperledger. All data stored by Pivot are encrypted in transit (HTTPS) and at rest (Amazon encrypted Elastic Block Store / Relational Database Service). User data is stored in a cryptographic ledger which helps to ensure integrity of data. Individual data records cannot be tampered with without changing the entire cryptographic hash

chain. All data, including logs, are stored either on Elastic Block Store (EBS) or in Amazon's Relational Database Service (RDS).

- **Data was a key driver and is a priority in Pivot** – Trip data from Pivot (stored on the Pivot Hyperledger Blockchain) are transmitted to the SCOS through a secure Application Programming Interface (API), allowing access to traveler patterns and behavior that was previously inaccessible to the City through mobility providers. Data is aggregated and de-identified to protect the identities of individual travelers and mobility providers. The Pivot routing engine uses machine learning to make recommendations based on traveler behavior and preferences, and to provide trip optimization based on current and historical conditions.
- **Seamless integration of payment remains an opportunity** – Pivot demonstrates that a MaaS platform is achievable, although links to third party apps for payment may be an interim solution to payment. True MaaS cannot be achieved without the seamless ability to pay for any combination of transportation services. Solidifying the enterprise architecture and gaining stakeholder consensus for the payment coordination is key to implementing all potential policies and agreements that are necessary for full integration.
- **To achieve MaaS, transit agencies should continue to serve in a key role.** Cities often have regulatory/permitting mechanisms for mobility providers, but public transit are better positioned to build relationships to encourage connection to transit and building a MaaS system. This process can and will take time, but may be mitigated by incremental development and integration, a strong project champion/owner, and incentivizing mobility provider participation.

The City will continue to operate and maintain Pivot going forward. Basic features and functionalities will be enhanced, building upon the existing metrics to include gamification and rewards. Trip history will be used to suggest alternate modes based on traveler activity, as well as using gamification to reward users with badges for using cost-effective and environmentally friendly modes of transportation. Pivot will integrate with COTA's new fare product, incorporate booking with COTA Mainstream and COTA Plus services, and additional mobility providers will be added as needed. The product roadmap will continue to evolve and grow as mobility behaviors return to normal post-pandemic, and as the transportation needs of the region change.

ES-4.4. Mobility Assistance for People With Cognitive Disabilities

Figure ES. 14: Mobility Assistance for People with Cognitive Disabilities at a Glance

Source: City of Columbus

People with cognitive disabilities rely on caregivers or paratransit[2] transportation services, which limits a person's ability to travel independently. The goal of the MAPCD project was to give people with cognitive disabilities the freedom to use public transit to travel. The app provides easy to understand, highly detailed turn-by-turn instructions for riding the bus, with trips developed and monitored by their caregiver.

[2] *Paratransit is a subsidized transit service that provides pick-up and drop off for individuals who are unable to use regular fixed-route transit services (for example, because of a developmental disability). Paratransit is expensive for transit agencies to provide, and high demand often means that trips need to be scheduled well in advance, limiting mobility.*

Wayfinder App Helps People with Vision Impairment Explore Central Ohio

Before joining the study, José relied on his family, caregivers, or the paratransit system to help him get around. After going through training on how to ride the bus and how to use the Wayfinder app, Columbus is José's oyster. **"It was a great experience because it provides directions and listening to the audio; it tells me what bus to get on and what stop to get off to go places like the North Market. You get to taste all different foods from different parts of the world like I'd never had before. It can help, not just me, but everyone, get around Columbus faster, more directly, and get to know the city to make it more fun and have good experiences."**

José, Mobility Assistance for People with Cognitive Disabilities participant, Clintonville

Individuals with disabilities comprise nearly 20% of the U.S. population (and will continue to include an increasing number of older Americans),[3] and many studies reflect the need to remove barriers to transportation options for people with visual, hearing, cognitive and mobility disabilities. The goal of the MAPCD project was to enable individuals with cognitive disabilities to travel more independently on the fixed-route bus service, many of whom relied on caregivers for transportation in privately-owned vehicles. To do this, the MAPCD project provided a solution from AbleLink (WayFinder) that offered accurate, customized turn-by-turn navigation with other support features ensuring that users with cognitive disabilities can safely and confidently complete a trip using the fixed-route bus service. The project team decided upon a "caregiver response model" to assist users, in which a relative or caregiver of the traveler monitors the trip and intervenes as necessary.

Figure ES. 15: WayFinder Application

Source: AbleLink

The MAPCD project was conducted in partnership with OSU, which played a critical role assessing the existing applications, conducting an evaluation of the technology, and completing a field study of wayfinding applications through the Pre-Vocational Integrated Education and Campus Experience (PIECE) program, a partnership between the Nisonger Center at OSU and Franklin County Board of Developmental Disabilities Adult Services. The MAPCD project launched in 2017 with initial research and definition of the user needs, and AbleLink was selected as the vendor in 2018. Application development and participant recruitment took place from late 2018 into early 2019, with 27 participants and their caregivers joining the study. After application enhancements and testing was conducted in the first quarter of 2019, the study launched in April

[3] https://www.its.dot.gov/research_archives/attri/index.htm

2019 with travelers and caregivers using the solution. OSU regularly engaged with participants for a 12-month demonstration via interviews and surveys to gather findings and results.

ES-4.4.1. KEY FINDINGS

- The primary benefit of the project was the increased independence, autonomy and community participation for individuals with cognitive disabilities. Specifically, the project addressed barriers encountered by individuals with disabilities. Some of these barriers include missing announcements of upcoming bus stops, automated stop notification not functioning correctly on fixed-route bus systems, or an inability to navigate public transit systems.
  - 91% of participants said the app and/or training enabled them to travel at least once a week
  - 76% of participants demonstrated a high level of independence after using the app[4]
- Initially, the project team envisioned cost savings for the COTA paratransit services; however, the results indicate that the is the increased independence, community participation and autonomy comprise the value-added component. So, local, regional and state organizations that focus on vocational opportunities for individuals with cognitive disabilities – particularly individuals with developmental disabilities – may realize the value. This was recognized in the Franklin County Board of Developmental Disabilities' project involvement, and the implementation of similar programs throughout the nation, including the Cuyahoga County Board of Developmental Disabilities.
- Technology solutions such as the WayFinder product are one aspect of implementation; while the MAPCD project demonstrated individual cases of success and satisfaction in terms of improving access, mobility and independence, widespread adoption (and, therefore, sustainability) requires coordination with transit agencies and community service organizations. Transit agencies ensure that access to General Transit Feed Specification (GTFS) is integrated into the solution and that travel training facilities are available, while community service organizations ensure access to the resources and personnel that are necessary for successful implementation.
- Two facets of participant satisfaction were assessed, since the MAPCD project involved both the traveler and their caregiver. The project findings indicated that these two sides are not always aligned in terms of satisfaction and perceived benefits: travelers were extremely satisfied with the increased independence, while caregivers were less satisfied by the time to build routes. This industry should continue to explore indicators that can accurately describe success from both sides. Mobility independence is key in connections to jobs and opportunity – which is critical to the economic vitality of these travelers. Mobility independence can be achieved, but it requires commitment from all stakeholders who contribute to the individual's care and well-being to achieve it. This can be a difficult trade-off in terms of convenience.
- A robust and flexible training plan improves success and satisfaction and may enable more independence. Modifications may be needed to the training protocol to make the training as effective as possible for each individual.

The City, OSU, and COTA are engaging with agencies and organizations that support those with cognitive disabilities to identify champions to maintain and support the program after the demonstration period ends. To assist in this transition, OSU has developed a detailed training plan and COTA will provide its training facilities to assist the champion agencies/organizations moving forward. AbleLink Smart Living Technologies will provide ongoing support for the WayFinder app after the demonstration period.

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[4] *Independence evaluated by participants' test scores when rated against their ability to complete a specific set of travel skills.*

ES-4.5. Prenatal Trip Assistance

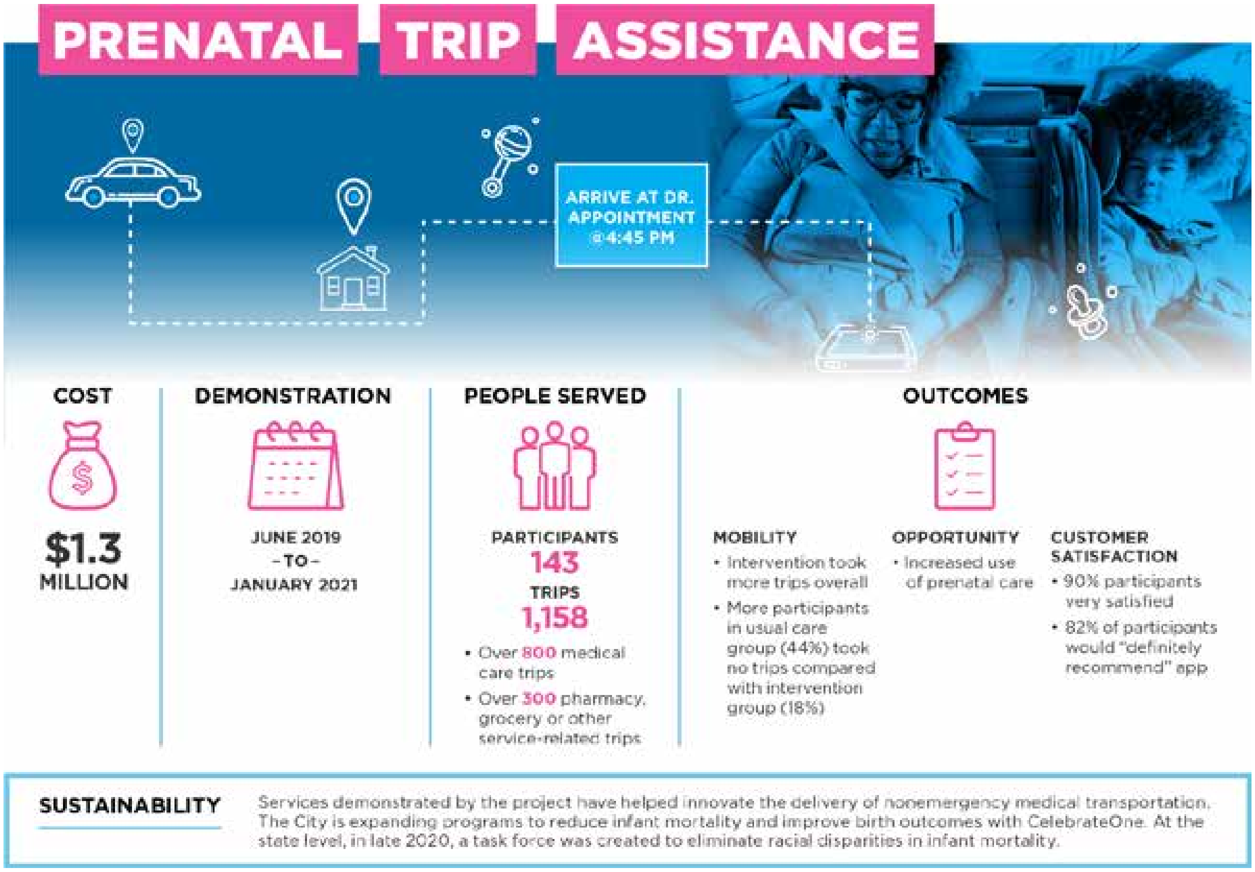

Figure ES. 16: Prenatal Trip Assistance at a Glance

Source: City of Columbus

Pregnant individuals face transportation barriers to receiving necessary medical care, which in turn, impact a city's infant mortality rates. The City of Columbus worked to make it easier for these individuals to get to their doctor appointments by connecting them with StepOne's care connectors who can ensure they are getting all they can out of the transportation benefit provided by their Caresource or Molina Medicaid insurance. The goal of the PTA project was to improve one of the factors that can impact preterm birth: transportation.

As far back as the initial SCC application, Columbus identified that there could be a link between reliable and safe transportation and medical outcomes, especially when it comes to Columbus' most vulnerable populations. Columbus has identified improved birth outcomes as an important goal, and Mayor Andrew Ginther previously created an initiative called CelebrateOne to combat infant mortality, because every baby deserves to celebrate their first birthday, regardless of race, address or family income.

Rides4Baby Partner Expands Transportation Benefits

"Caresource is always looking for innovative ways to improve health outcomes for pregnant women. We've gained valuable insight from Rides4Baby and are now expanding same-day transportation benefits to better serve our clients."

Donna Gabbard MSN, RN, MHA, CCM, Director, Women & Children's Health at Caresource

The PTA project focused on non-emergency medical transportation (NEMT) services delivered by Ohio's Medicaid MCOs to study whether changes in NEMT services can impact premature birth and thereby lower the rate of infant mortality.[5]

The PTA project developed a solution for a technologically advanced NEMT service. This project enhanced mobility and increased opportunity, efficiency, and customer service for pregnant individuals who used Medicaid-provided NEMT. PTA also provided sources of high-quality data for the Ohio Department of Medicaid, MCOs, and others researching prenatal care of Columbus Medicaid recipients.

Project participants could schedule their rides through three flexible, on-demand options: a call center, website or smartphone app (Rides4Baby). The PTA system connected NEMT service providers with the participant, enabling multiple transportation reminder texts, emails or calls, and real-time driver location information, so participants were ready for pickup and avoided long waits. The system also transferred driver information directly to the participant, giving them the extra security of knowing what type of vehicle to expect.

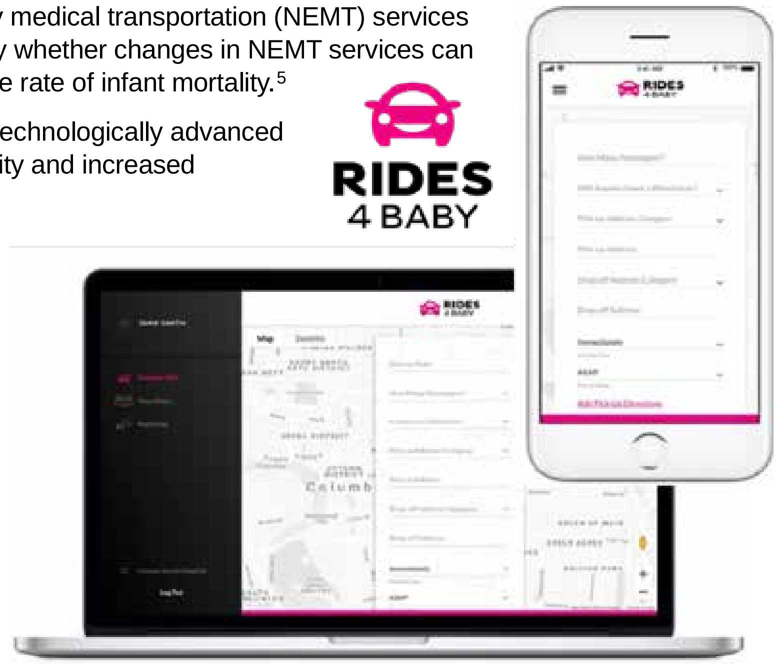

Figure ES. 17: Rides4Baby Website and Mobile Application

Source: Kaizen Health

The PTA project team started recruiting participants on May 31, 2019, and the last data for the project was collected on January 12, 2021. Because this project targeted a specific use case to test transportation technology, an experienced research partner was imperative. Researchers from the OSU Wexner Medical

[5] *Infant mortality is defined as the death of an infant before age 1 and is a global indicator for population well-being.*

Center provided the background, expertise and passion required to execute the PTA project. The OSU researchers provided complete oversight of the study including creation and implementation of the research protocol, and communication and interaction with participants.

Figure ES. 18: Prenatal Traveler

Source: City of Columbus

ES-4.5.1. KEY FINDINGS

- While a standalone intervention such as the provision of enhanced smart NEMT services are unlikely to meaningfully reduce adverse birth outcomes, including infant mortality, preliminary work suggests that it may be a valuable contribution to providing individuals the wrap-around care needed during the pregnancy and postpartum periods.[6]
- Participants assigned to the usual care group (for whom NEMT trips are available through MCO-based call centers) took fewer trips than those in the PTA project's intervention group. Over the study period, participants in the usual care group took a median of two trips; those in the intervention group took a median of 19 trips. More participants in the usual care group (44%) compared with the intervention group (18%) took no trips at all during the study period.
- There was a strong suggestion of increased satisfaction in the intervention group compared with the usual care group, with 90% and 79% reporting being "satisfied" or "very satisfied," respectively.
- Among participants randomly assigned to the intervention group who used the mobile app to schedule a ride, 82.8% said that they would "definitely recommend," and 13.8% indicated that they would "probably recommend" the Rides4Baby mobile app to other pregnant individuals.
- Of the participants assigned to the intervention group, 93.1% reported being very satisfied or somewhat satisfied with the mobile app. Regarding the ease of learning the mobile app, 98.3% were very satisfied or somewhat satisfied.
- In examining the adequacy of prenatal care that participants received, there was no notable difference in prenatal care use between the groups, with 66% receiving adequate or adequate plus prenatal care in the usual care group versus 69% in the intervention group. Prenatal care information was missing for 12 members, or 8%, of the study cohort due to miscarriage or missing vital records data.
- No meaningful difference was observed in preterm delivery between the usual care and intervention groups, with term birth proportions of 77% and 69%, respectively. Final infant mortality data will be available, at the soonest, in January 2022; however, investigators have not report any infant deaths among the study population to date.

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[6] *Even in communities with high rates of infant mortality, most individuals have access to a smartphone and can navigate a mobile app to schedule a ride. The PTA project's provisions of on-demand transportation and flexibility in available destinations (e.g., the food bank or grocery store) increases users' satisfaction, which makes them more likely to use the available NEMT services.*

While the City does not operate NEMT, the MCOs' changes to NEMT during the COVID-19 pandemic demonstrates that the project gave the organizations the information they need to think innovatively as they negotiate new transportation contracts. CelebrateOne and the City continue to advocate for additional programs focused on reducing infant mortality and improving birth outcomes. In late 2020, the State of Ohio created a task force to eliminate racial disparities in infant mortality. PTA project data is expected to be helpful in developing solutions as the task force includes representatives from the City and from the MCOs that participated in the PTA project.

ES-4.6. Smart Mobility Hubs

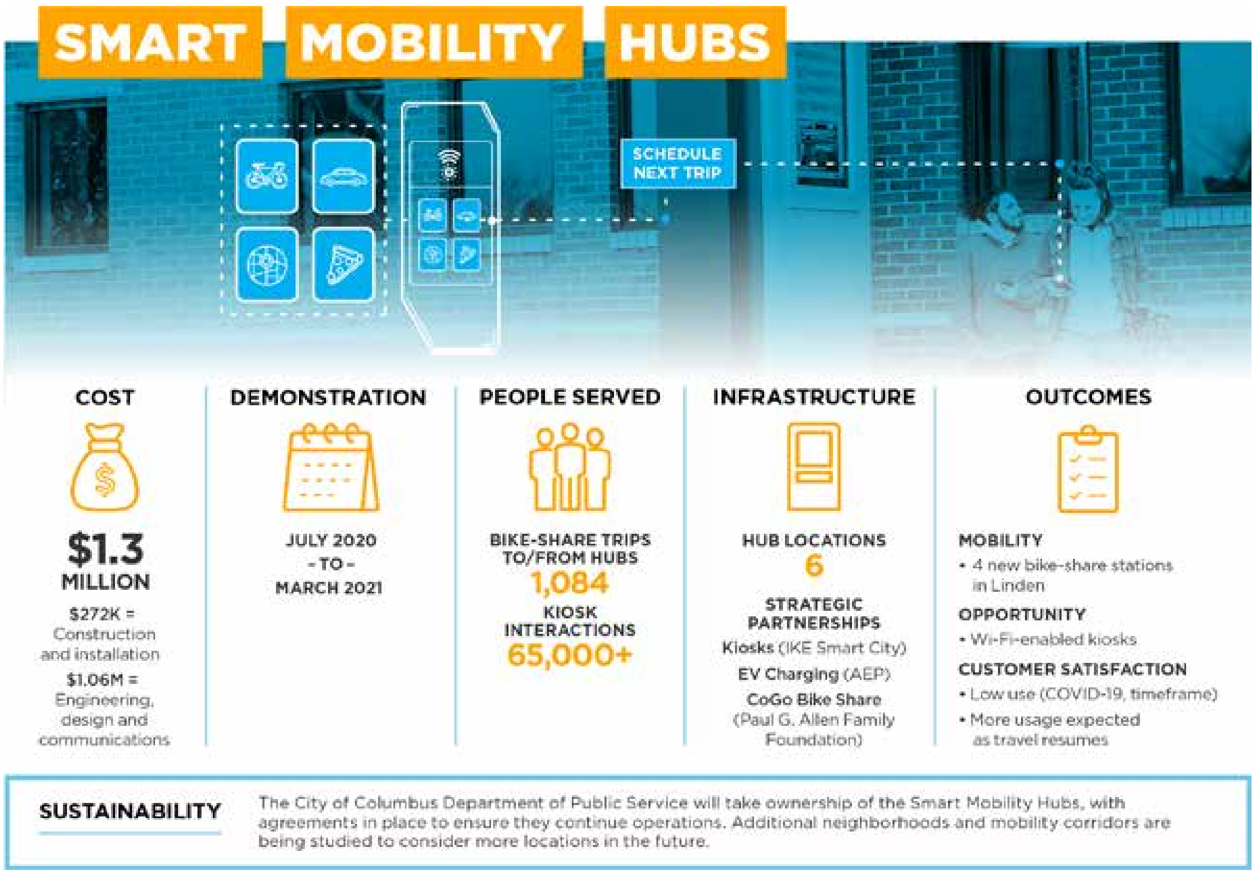


Figure ES. 19: Smart Mobility Hubs at a Glance

Source: City of Columbus

People in Linden and Easton struggle to find transportation options to fill the gap between bus stops and their homes, jobs and other destinations (called the "first-mile/last-mile problem"). SMHs connect people with alternative transportation choices such as bike- and scooter-sharing, or ride-hailing services, via six locations near bus stops. A real-time, interactive information kiosk, called IKE, anchors each hub and provides information about mobility options – including the Pivot app – as well as free Wi-Fi and other community resources. The project's goal was to improve mobility and increase access to jobs, education, and services for Linden and Easton visitors, employees and residents.

Bike-Share Provides First Mile/Last Mile Connections from Smart Mobility Hubs

"By placing CoGo Bike Share stations at Smart Columbus Mobility Hubs, we are able to integrate an important first mile/last mile solution for the Linden community that helps residents complete connections to the greater transportation network and links them to essential resources like healthcare, libraries, groceries and jobs."

Chet Ridenour, CoGo Bike Share Operations Manager

The SMH project was designed to improve the availability of transportation options for people living in areas with limited connectivity. The Linden neighborhood was identified as the focus area for the project, as its residents face numerous socio-economic challenges, including low household income, lack of major employers, and high infant mortality rates. These problems are compounded by the lack of access to transportation options, as there are numerous job centers throughout the Columbus region, including some a short drive from this neighborhood. Easton is a high-traffic retail destination and office center in the northeast part of Columbus, just a few miles from Linden. Although Easton is a major employment center, the jobs in this area have a high turnover rate. Research has shown that a major contributor to this type of job instability is the lack of reliable transportation, including first-mile/last-mile challenges related to safety and mobility.

Figure ES. 20: Linden Library Smart Mobility Hub

Source: City of Columbus

Six SMHs were deployed to provide travelers with consolidated transportation amenities such as Interactive Kiosks (IKs) with Wi-Fi and emergency call buttons (ECBs), enabling modal transfers between a variety of transportation options that exist in the City, and providing access to comprehensive trip-planning tools such as Pivot. Taken together, these services made it easier and more convenient to make multimodal trips, including coordinating first mile/last mile connections. Project construction was completed in January 2020, but the hubs did not officially open to the public until July 2020 due to the COVID-19 pandemic. The deployment of the SMHs was inexpensive, as significant construction was not required, with expenses of approximately $250,000 on infrastructure (concrete, signage, pavement markings) and bike-share stations and bikes to deploy six hubs.

Leveraged partner contributions were key to this effort:

- The City coordinated with COTA to apply for an AEP grant for EV charging at the Northern Lights Park and Ride
- The City of Columbus was able to leverage the existing kiosk contract that is advertisement-supported to install the six kiosks at no cost to the City.

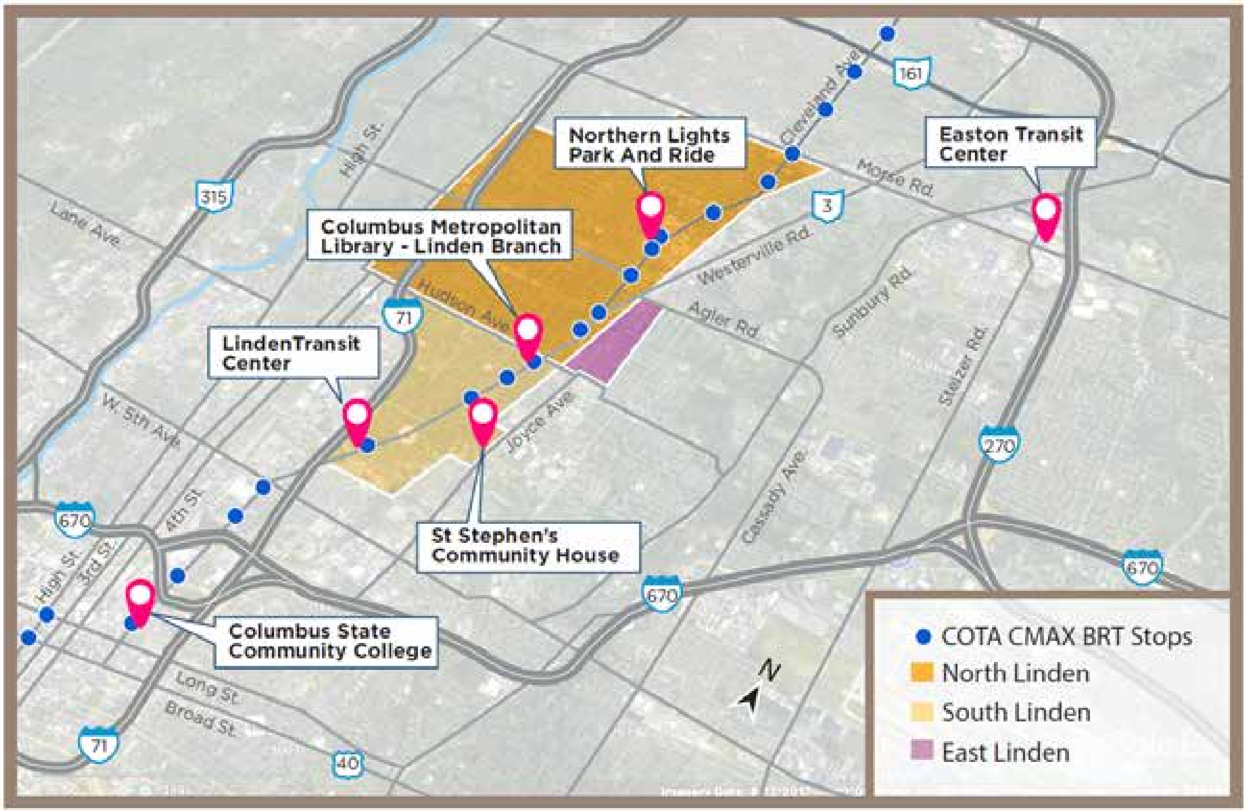


Figure ES. 21: Smart Mobility Hub Locations

Source: City of Columbus

ES-4.6.1. KEY FINDINGS

- Once a vision for the project concept, user needs, and participating mobility providers are identified, the construction of the sites can be accomplished quickly. In the case of the SMH, site survey, design, permitting, and construction can be accomplished in months, if using in-house resources (City employees) to construct.
- Most of the CoGo bike users who began their rental at an SMH returned the bicycle to that same hub.
- The introduction of the electric pedal-assist bicycles at the SMHs was successful, and the option became a very popular choice, accounting for 46% of bike-share trips at the SMHs since their launch.
- The Linden Transit Center had the most foot traffic and St. Stephen's Community House had the least amount of traffic. Due to COVID-19, St. Stephen's had reduced programming, limited guests in the building, and was closed to visitors for some time during the demonstration period. The project team noted that because the kiosk was located inside the building, interactions with the IKs were drastically limited.

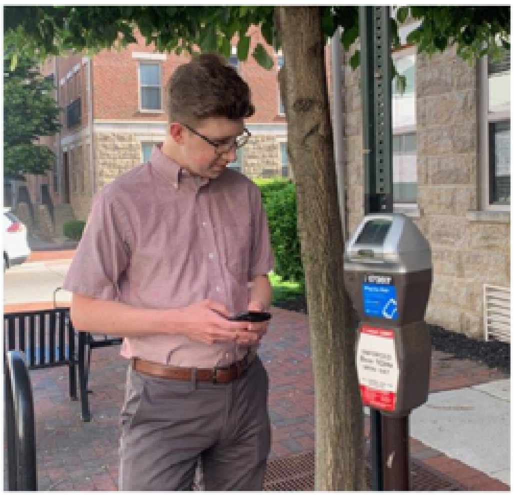
The City of Columbus Department of Public Service will take ownership of the SMH project after the demonstration period and coordinate further implementation. Additional neighborhoods and mobility corridors are being studied as part of the City's mobility plan, LinkUS. Opportunities to include SMHs in LinkUS will be identified and prioritized for implemented using the framework developed by the Smart Columbus Program and COTA's mobility hub program. The existing SMH sites have agreements with the private property owners to ensure they continue beyond the project.

ES-4.7. Event Parking Management

Figure ES. 22: Event Parking Management at a Glance

Source: City of Columbus

In Columbus' busy Downtown and Short North neighborhoods, finding parking is difficult. The City of Columbus expanded the features of the ParkColumbus app to be a one-stop-shop to easily find and pay for parking in garages, surface lots, and streets. The app is powered by real-time data from parking management operators and predictive analytics flowing through the SCOS. The goal was for people to be encouraged to eat, shop, and play in the Short North and Downtown due to the ease of parking, while congestion and emissions are reduced by fewer drivers circling for parking.



Downtown Young Professional Uses ParkColumbus for Work and Play

Robert is a young professional that works in Downtown Columbus. He prefers to ride the bus or bike to work but depending on the weather or his work that day, he sometimes opts to drive. He uses ParkColumbus to find a long-term parking spot during his work day. Robert lives in Merion Village, south of Downtown, but finds himself in the Downtown or Short North a lot. **"When I'm headed to the Short North for dinner or drinks, I check the on-street parking availability to see how busy it is to decide if I attempt to find a spot or head to a garage or further out parking spot directly. My partner and I are avid Columbus Blue Jacket fans and now that games have started up again, I can use ParkColumbus to reserve a spot in advance so I'm not stranded by the bus after hours or paying surge pricing for a ride-hail home."**

Robert, ParkColumbus User, Merion Village

The EPM project is the future of smart parking in Columbus. The project implemented new features into the ParkColumbus app and created a website to allow users to identify currently projected parking availability near their target destination, and aids in effectively reducing the additional driving required to find parking options. This system provides users access to parking reservations and payment capabilities for garage and surface lot parking. Benefits of the EPM project include reduced congestion, traveler frustration, and emissions.

Focused originally on parking around major events, the final solution expanded based on discussions with end users and the need to accommodate future growth. This growth includes gains in tourism and business travel in the urban core during regular business days as well as events such as festivals, conventions, sporting events and marathons. The geographic scope of the EPM project focused on providing parking availability information for parking garages, surface lots, parking meters, and loading zones in downtown Columbus and the Short North Arts District. The project also enabled sharing of location and restriction information on the City's loading zones, and provides the location of on-street EV-charging and handicap accessible parking spaces citywide. Real-time and historic parking meter data is collected and sent to the SCOS to be run in an in-house, custom produced, open-source algorithm built by the SCOS team to calculate and predict the availability of parking.

ES-4.7.1. KEY FINDINGS

- Since the launch of the ParkColumbus app, the share of credit card payments made within the app has grown rapidly to be greater than the credit card payments made at the meters: 52% versus 47%, respectively, essentially reversing this allocation in the time since ParkColumbus originally launched in 2019 (prior to the addition of new features developed through the EPM project).
- New registrations have remained steady since the new features were announced in December 2019, with over 4,500 new registrations each month (January and February of 2021 were over 5,400).
- Leveraging existing relationships and projects enabled the team to work with a vendor that had established trust with the project team while still developing and integrating innovative and customized components into the system:

- ParkMobile previously worked with the City's Division of Parking Services as a subcontractor to Conduent on their mobile payment project. This created development efficiencies in procurement while also providing a built-in user base from ParkColumbus and an established connection to the parking operators, easing the completion of necessary agreements to solidify their participation.
- The parking prediction model was developed in-house within the contract for the Operating System team. Similar models were not ready to be tested or were cost-prohibitive and proprietary. The Operating System team's solution was less expensive, customized to Columbus (since it used data from the City and ParkMobile in the model) and open source, making it accessible to other cities.

Figure ES. 23: ParkColumbus Predicted Parking Availability

Source: City of Columbus

While the EPM project was one of the smaller projects in the portfolio in terms of size, the strong project champion from the City's Division of Parking Services and an established vendor ensured success despite overall reductions in travel and parking following the COVID-19 pandemic. The City will operate and maintain ParkColumbus, including the parking prediction model, going forward.

ES-4.8. Connected Electric Autonomous Vehicles

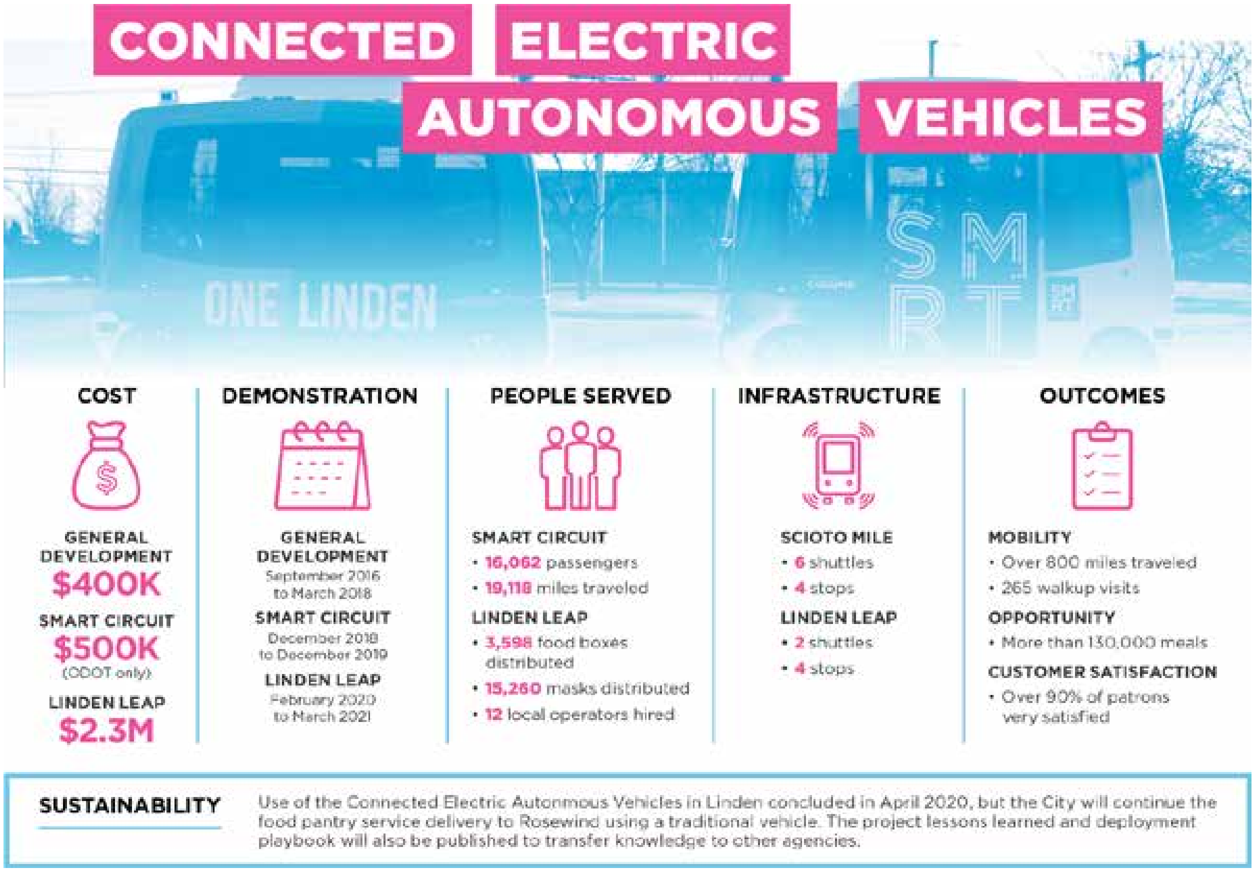


Figure ES. 24: Connected Electric Autonomous Vehicle Projects at a Glance

Source: City of Columbus

The City of Columbus demonstrated two CEAV deployments through the Smart Columbus Program. While the original vision was for the technology to serve multiple routes in the Easton area of Columbus (connecting existing transit routes to jobs and businesses), technology readiness was a barrier to deployment. The City worked with partners and stakeholders to determine new routes in the downtown and Linden area to serve the public during the demonstration period.

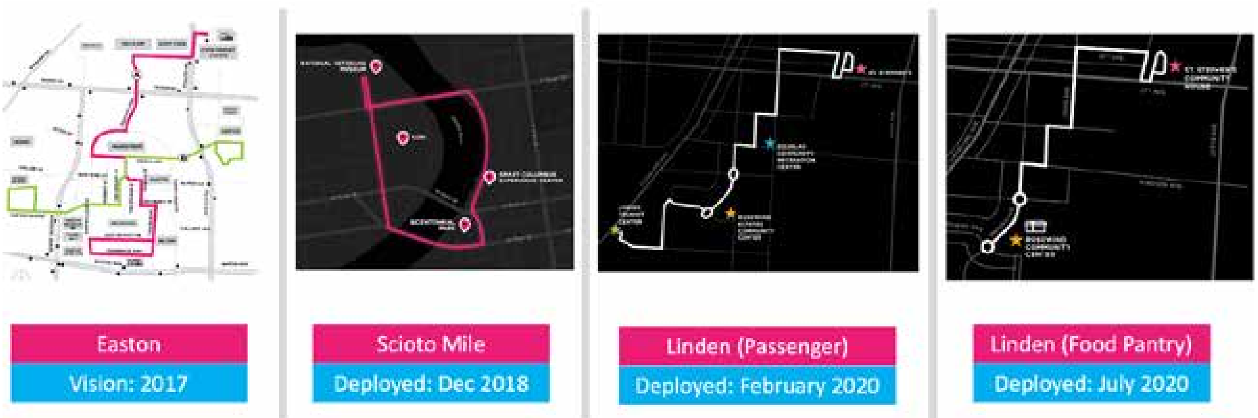


Figure ES. 25: Summary of Connected Electric Autonomous Vehicles Deployments

Source: City of Columbus

The Scioto Mile deployment with May Mobility in downtown Columbus served area attractions and cultural resources like the Center for Science and Industry (COSI), Veteran's Memorial and the Smart Columbus Experience Center. This service operated from December 2018 until September 2019.

The second deployment with EasyMile served as a first mile/last mile connection to transit in Linden. The Linden LEAP (Linden Empowers All People) launched February 2020 and operated for about two weeks before an on-board incident paused passenger operations. When the COVID-19 pandemic impacted the ability to return to passenger service, the City reimagined the mission of the vehicles, launching a food pantry delivery service in July 2020, concluding in April 2021.[7]

Figure ES. 26: May Mobility Vehicle

Source: City of Columbus

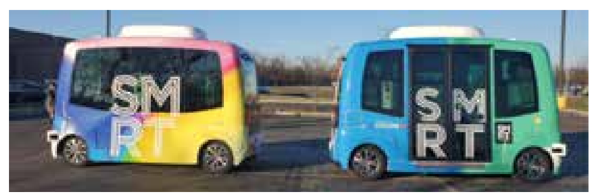


Figure ES. 27: EasyMile Vehicles

Source: City of Columbus

ES-4.8.1. KEY FINDINGS

- A vehicle operator (driver) was on board all CEAV vehicles at all times to ensure safety, and small parts of some routes were designated for nonautomated operation (e.g., crowded parking lots and stop-sign controlled intersections).
- Autonomy was found to be affected by weather and other variables. This can impact service reliability if operations are regularly suspended or slowed.
    - Operating in light rain, mild fog and light snow events seemed a reasonable expectation when developing the procurement documents, based on other AV demonstrations in Norway and Minnesota. The reality is that most precipitation hindered the operation of the vehicles in

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7 *Grant regulation 2 CFR §200.313(c)(2) allows the federal government to approve temporary use of grant equipment for non-federally funded programs or projects, provided that such use will not interfere with the work on the projects or program for which the grant equipment was originally acquired.*

autonomous mode. There are other variables, such as the exhaust from gasoline-powered vehicles in colder months, which can cause the vehicle to stop suddenly, or sun glare at certain times of the year that can cause the vehicle to slow down.

- Smart Circuit became the first AV deployment in Ohio when it launched for passenger service on December 10, 2018.
  - During its 10-month operation, Smart Circuit carried 16,062 passengers, an average of 59 riders per day.
  - The six shuttles drove 19,118 miles during the demonstration.
  - The Smart Columbus Experience Center stop was the most popular among Smart Circuit riders, with 55% of ridership using that stop.
- An unexpected result of the Scioto Mile service was its regular use by some commuters who parked on the west side of the river where parking was cheaper and used the service to travel into downtown.
- During its initial two weeks of operation of the Linden LEAP passenger service, 50 passengers took rides on the Linden LEAP, with the vehicles operating at greater than 70% automated mode on a challenging route.
- The Linden LEAP food pantry service averaged 100 boxes per week throughout the project and saw strong and steady distribution throughout the project.
  - Almost 9% of the food pantry service patrons walked to the shuttle and did not drive, so bringing the food into the community eased the two-mile walk to and from the food pantry with a 30- to 40-pound box.
  - With each box containing 36 meals (three meals per day for four people, and three days' worth of food), the Linden LEAP pantry service distributed 129,528 meals into the community during its eight months of food delivery.
  - More than 80% of patrons said they were satisfied with the convenience of the service.

Linden Leads Neighborhood Innovation to Serve Residents Now and in the Future

Ms. Peg is a grandmother and woman of faith that lives on Cleveland Ave. in Linden. While the Linden LEAP was providing passenger service, she walked .3 miles to the stop at Douglas Recreation Center to pick up the LEAP to get to St. Stephen's for services and community events or to Maloney Park to walk the trail. **"I mainly rode it to learn the route and experience what it was like to be a passenger on an autonomous vehicle. I would ride it when I was short on time or had heavy things to carry with me. I'm ready for the automobile that drives itself and all I have to do is give it verbal instructions."** Ms. Peg had her car totaled during the pandemic but didn't see a need to replace it right away. Usually she would pick up a food pantry box once every two weeks from St. Stephen's but without a vehicle she would have needed to depend on others to take her.

When the Linden LEAP expanded the service of the food pantry to the Rosewind Community Center, Ms. Peg was able to continue getting food without having a car. **"It was nice to have Linden noticed for something positive. And now Linden is a leader in this space and has the infrastructure, data, and experience to be prepared for future innovations. It's also a plus that what was learned here will shape pilots in other communities that look like Linden so they're on the forefront of innovation as well."**

Ms. Peg, Linden LEAP participant, Linden

- Communications and engagement with a wide variety of stakeholders was critical to both projects. Partnering with trusted community organizations informed the outreach strategy and execution and provided necessary third-party validation. Aside from directly engaging with residents, the Team also engaged agency stakeholders early and often, especially during the development of the route, user needs, and operating procedures, as well as during testing.
- Data collection and analysis for the Linden LEAP was a project success. The City created robust requirements around data collection between the first and second procurement to collect as much operational data as possible. Data is the key to understanding the current capabilities of the technology, and how operational challenges can be overcome.
- The greatest assets for a deployment are local and in the community. The Linden LEAP was a community-based project, which fostered ownership and pride in the effort. The community was engaged in naming the shuttles and the route and had its own launch event featuring the robotics team from the local STEM[8] school. EasyMile contracted EmpowerBus, a local operator that hired local people that greeted riders and operated the shuttles. After EmpowerBus went out of business due to the pandemic, EasyMile directly hired the operators to continue the service and distribute food into the community.

8 *The Linden-McKinley STEM Academy is a public Middle School and High School with a curriculum that focuses on science, technology, engineering, and math (STEM).*

- Without flexibility, the project team may not have been able to deliver a successful project in Linden due to the sudden stop incident and pandemic as confounding factors. Rethinking the mission of the vehicles to still meet the needs of the community allowed for a successful transformation of the deployment, despite the circumstances.

The vehicle demonstrations ended with the conclusion of this project, although the City is continuing food pantry delivery from St. Stephens Community House to Rosewind using a traditional vehicle. The lessons learned and deployment playbook developed as a result of this project are already aiding new deployments through DriveOhio and other states.

ES-5. RESULTS AND CONCLUSIONS

Summarizing the results from a program of this size, scope and duration was considered from various perspectives. The performance measurement results provide a quantitative assessment of the program and each project against a defined set of indicators that tie directly to the six outcomes identified in the program vision. The City has continually kept the USDOT's 12 Vision Elements for the Smart City Demonstration (as identified in USDOT's SCC, and **Section ES-5.3** below) at the forefront while developing and implementing the projects.

ES-5.1. Performance Measures Results

The primary objective of the Smart Columbus Program was to demonstrate, quantify, and evaluate the impact of advanced technologies, strategies, and applications toward addressing urban mobility challenges. The performance measurement findings help clarify the impact of the integrated Smart City solutions on the six program outcomes: safety, mobility, opportunity, environment, agency efficiency and customer satisfaction.

After almost five years, the Smart Columbus Program was found to have successfully or partially achieved 22 of the 29 objectives identified for the program. Performance on the remaining seven objectives was inconclusive primarily due to small sample size or COVID-19 impacts, not project or application failures:

- The CVE Safety outcomes were 100% successful in all three objectives.
- Opportunity objectives, assessed for the program and individually as part of the MMTPA, MAPCD, PTA and CEAV projects, were also found to be 100% successful for the five objectives.
- The Mobility and Customer Satisfaction outcomes were successful in the majority of objectives but produced inconclusive results for some objectives.
  - The impact of COVID made it especially difficult to gather the necessary data for mobility objectives.
- The Environmental objective was also inconclusive due to the small amount of data and limited length of demonstration of the contributing projects (CVE, MMTPA and EPM).
- The Agency Efficiency outcome was successful or partially successful in four out of five objectives, with inconclusive results for one objective. This was a result of the MAPCD project not recruiting participants who had previously used paratransit.

Figure ES. 28 summarizes the key findings from this analysis.

OUTCOMES →	SAFETY	MOBILITY	OPPORTUNITY	ENVIRONMENT	AGENCY EFFICIENCY	CUSTOMER SATISFACTION
CONTRIBUTING PROJECTS	→ CVE	→ SMART COLUMBUS PROGRAM → MMTPA → SMH → MAPCD → PTA → CEAV	→ SMART COLUMBUS PROGRAM → MMTPA → MAPCD → PTA → CEAV	→ SMART COLUMBUS PROGRAM *Projects assessed as a group:* → CVE → MMTPA → EPM	→ SCOS → MAPCD *MAPCD project assessed as "inconclusive; because participants were not existing paratransit users*	→ SCOS → MMTPA → SMH → PTA → EPM → CEAV
PROGRAM FINDINGS	*Not applicable; only CVE project evaluated for Safety benefits*	Improved ease of transferring modes Modest reduction in traffic delays and traffic volume observed during peak weekday hours	Significantly easier trip planning post-Smart Columbus Accessibility area expanded by 30 minutes from Linden Transit Center Established access to 20,000 more jobs and 3,000 more health care services	Inconclusive due to small sample sizes and impact of COVID-19 pandemic on travel behavior Projects assessed as a group have potential to reduce greenhouse gas emissions post-pandemic	*Not applicable; only SCOS and MAPCD projects evaluated for Agency Efficiency benefits*	*Not applicable; Customer Satisfaction evaluated only at project level*
HIGHLIGHTS OF PROJECT OBJECTIVES ACHIEVED	**CVE:** • Emergency response times (average speed and travel time) improved by average of 1.64% when signal preemption granted; improvement of up to 5.2% noted • Vehicle speeds reduced by average of 2.3 mph when approaching red light • School zone speed limit compliance improved from 18% to 56%	**EPM:** Significant improvement in mean response time taken to find parking for leisure activities **MAPCD:** Shifted 82 trips from the personal vehicles of caregivers to public transit **CEAV:** 265 walkups at the Rosewind stop	**MMTPA:** Significant increase in access to health care and entertainment **MAPCD:** Participants reported sense of greater independence **PTA:** Percentage of participants who did not take NEMT trips decreased from 44% to 19% **CEAV:** Over 130,000 meals transported to neighbors in Linden	**PAUL G. ALLEN FAMILY FOUNDATION GRANT:** • 3,458 EVs purchased • 914 charging ports installed • 18.6 million people educated about Smart Columbus Program	**SCOS:** • Over 800 agency-related datasets • 222,685 downloads • 67,156 queries • 59% of users rated their experience of finding intended data as good to very good • Agency users cited improved data-sharing ability • Over 60% of users said experience accessing and using data was good to very good	**SCOS:** Over 70% rated various functions good or very good **MMTPA:** Over 97% found Pivot easy or very easy to use **PTA** and **CEAV:** 90% were satisfied, very satisfied or extremely satisfied **EPM:** Over 30,000 app downloads; 82% users say they will use new app features

Figure ES. 28: Highlights of Performance Measures Results

Source: City of Columbus

ES-5.2. Resident Impacts

Outside the scope of the six outcomes defined in the Performance Measurement Results, OSU also evaluated the economic and accessibility impacts of the program:

- The economic analysis calculated a short-term impact of $147.86 million in gross metropolitan product (GMP), $51.05 million from direct investments by the program, and $96.82 million in indirect effects, through impacts on the supply chain and increased household spending. Furthermore, investments by the program are likely to generate an increase of 4,220 jobs, with approximately 719 jobs generated as a direct effect of the expenditure from the Smart Columbus Program-related staffing, with the remaining 3,501 attributable to the indirect effect on the affected sectors through the supply chain. The long-term projected impacts have more uncertainty, due to the difficulty in projecting future effects of the program. However, assuming the successful deployment of the Smart Columbus Program projects, utilization of the services is likely to generate a $671.28 million or 0.5% increase in GMP, and 7,039 jobs (an employment increase of 0.3%). Overall, the multiplier of the Smart Columbus Program investment was found to range between 1.71 and 2.09, indicating that each dollar invested in the Smart Columbus Program is associated with an increase of between $1.71 and $2.09 in value added to the local economy.
- The accessibility analysis evaluated the improvement in potential mobility provided by the application of Smart Columbus projects to access employment and community services. It utilized the Linden Transit Center as a representative starting location, and examined public transit routes and schedules, sidewalk networks, the location and availability of docked and dockless micromobility options, and other information to compute the area that could be reached within a set travel time (30 minutes) both with and without the Smart Columbus project improvements. The analysis then computed the number of job and health care locations that could be reached within the set travel time with and without the improvements.
  - The accessibility area (defined as the area a traveler could reach within 30 minutes) expanded regardless of the time of day assessed (9 a.m., 1 p.m. or 6 p.m.), as illustrated in **Figure ES.** 30.
  - As a result of the expansion, travelers would be able to reach at least 20,000 additional jobs and 3,000 additional health care services than they would using the trip planning tools that existed prior to the introduction of the Smart Columbus projects. The increase in accessibility was even greater for certain classes of jobs and services and at certain times of day.

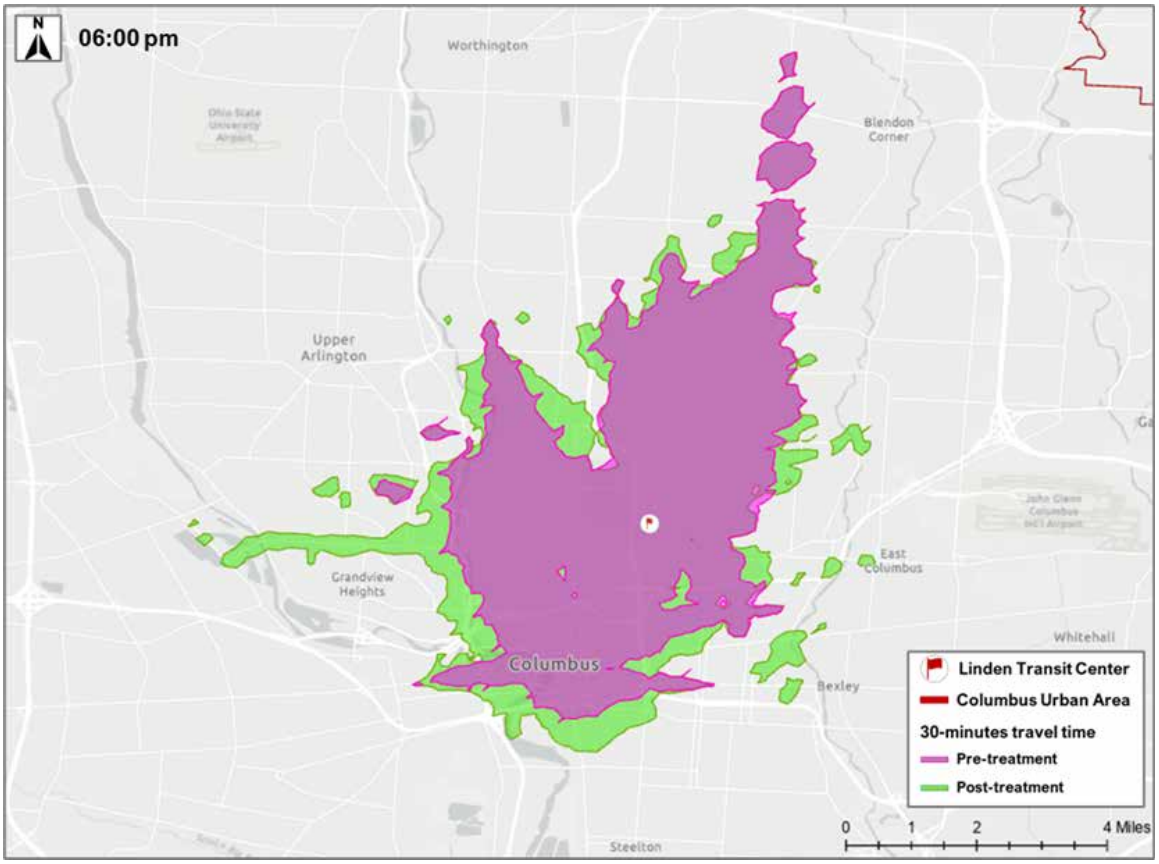

Figure ES. 29: The Ohio State University Accessibility Analysis

Source: OSU

- These accessibility improvements can provide benefits to those living close to or interacting with the SMHs. Specifically, OSU's housing assessment analyzed SMH-adjacent neighborhoods to determine if they displayed new housing market activity relative to similar neighborhoods. The housing analysis results provide context for how neighborhoods may evolve in the future:
  - A sizeable effect of SMHs on short-run market activity was found that implies a 33.5% increase in sales likelihood for residential parcels.
  - However, evidence was inconclusive regarding any change in housing prices due to proximity to SMHs.

ES-5.3. Achievement of USDOT Vision Elements

Figure ES. 30 depicts the Smart Columbus projects that demonstrate the 12 Vision Elements identified by the USDOT in the SCC. Applicants were encouraged to consider these 12 elements in developing ideas for their smart city demonstration to address real-world issues and challenges that citizens and cities face. Aligning Columbus' goals with USDOT's Vision Elements required a holistic approach to addressing transportation challenges faced in the City. Each project addressed multiple USDOT Vision Elements, as described in each project chapter. The specific achievement and example of how each project satisfied these elements was not always what was originally anticipated but demonstrates the importance of keeping this vision at the forefront of the planning and deployment efforts.

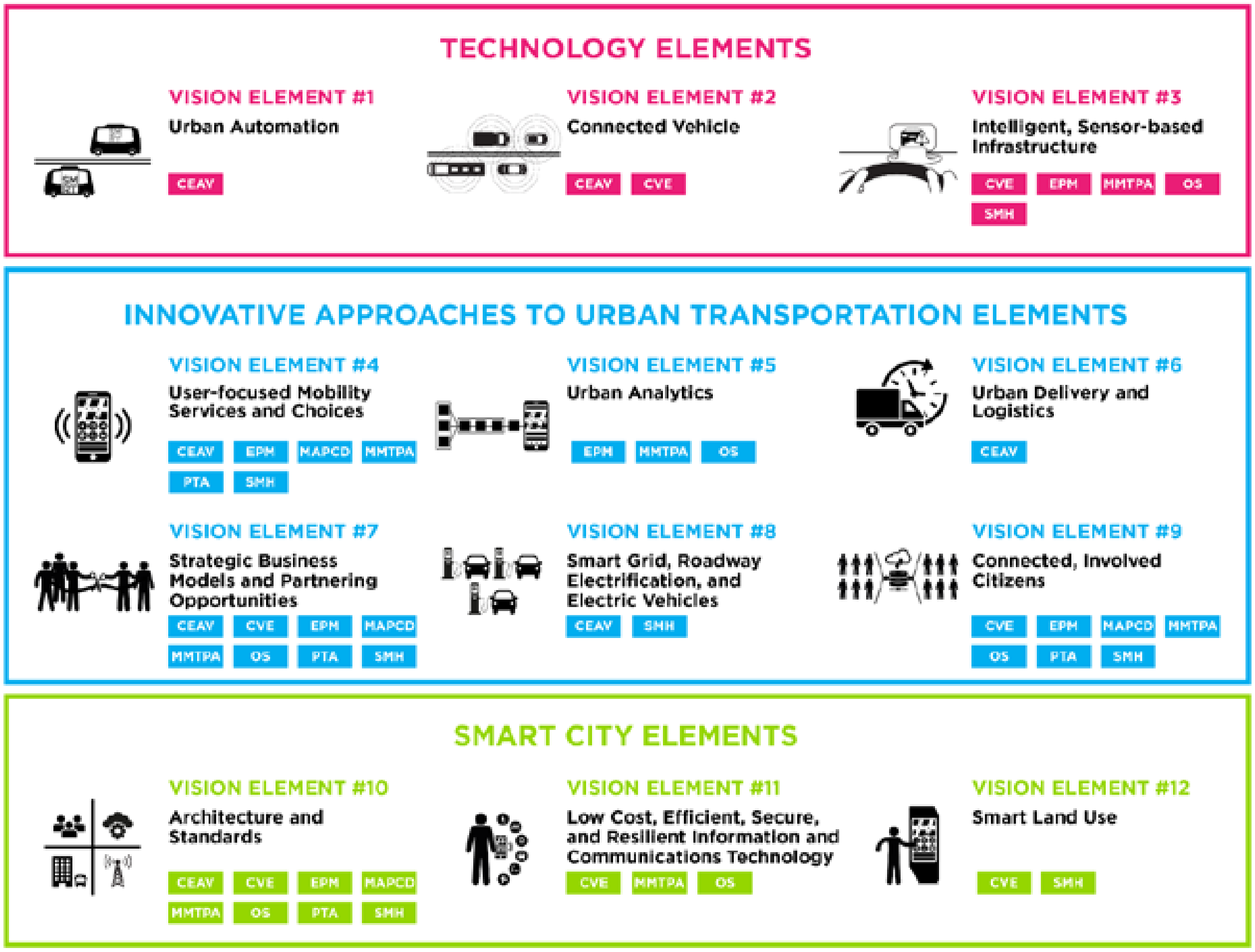

Figure ES. 30: Smart Columbus Program Alignment with USDOT Smart City Vision Elements

Source: City of Columbus

ES-5.4. Local Legacy and Enduring Outcomes

While the performance measurement results contain the tangible scientific results of the program when measured against the defined indicators of the plan, there are many examples (both quantitative and qualitative) that also speak to what the City of Columbus achieved through the implementation of the program.

ES-5.4.1. SUSTAINABILITY

The SCC sought projects that would be sustainable, and the City worked closely with stakeholders to establish projects that could take hold and continue beyond the Cooperative Agreement. Working together as a region ensured there was adequate investment from public, private, and institutional sources to sustain the Smart Columbus Program vision both during the demonstration and beyond. With the study phase largely completed, Columbus is continuing to support the advancement of the SCOS, EPM, CVE, SMH and MMTPA projects. The Columbus Department of Public Service has taken ownership of these projects and identified funding for operations, maintenance, and enhancements.

- The City will own the **SCOS**, continuing to provide data-driven analytics to evaluate mobility and transportation investments and help City departments optimize safety and efficiency. The Operating System will continue to serve the needs of the City by collecting data and providing analytics tools for use by the City and the general public.
- **EPM** provided important enhancements to the ParkColumbus app, which will continue to be one of the key solutions used by the City's Division of Parking Services to provide accessible, equitable and predictable mobility and parking options for all residents, guests and visitors.
- **CVE** RSU and OBU vendors are funded to operate and maintain their assets for a period of 15 months after the demonstration; the City is also continuing coordination with DriveOhio and the City of Dublin to test interoperability with other CV deployments managed by DriveOhio.
- The six sites of the **SMHs** will be taken over by the City's Department of Public Service, while additional neighborhoods and mobility corridors are being studied for new SMH locations as part of the City's mobility plan.
- The City will sustain the **MMTPA** "Pivot" app through January 2022. Basic features and functionalities will be enhanced, and the app will be improved to include gamification and rewards for using cost effective and environmentally friendly modes of transportation, as well as accommodating the ever-changing landscape of mobility providers.

Beyond the term of the Cooperative Agreement, the Smart Columbus initiative will continue as a public-private partnership co-led by the City of Columbus and The Columbus Partnership, with a charge that extends beyond mobility, and positions the organization as an agile, collaborative innovation lab for the city of the future. As such, Smart Columbus will serve to accelerate and advance what's next at the intersection of technology and community good. Projects already underway at Smart Columbus include a broadband pilot that will help to close the local digital divide, an app that will facilitate the criminal record sealing process to create pathways to the middle class for those who have served their time, and a corporate renewable energy buying program that will improve local air quality and fight climate change.

ES-5.4.2. SMART CITY PROGRESS AND OTHER REGIONAL COLLABORATIONS

The Smart Columbus Program was part of a wide range of inspired and invigorated community initiatives that are exploring what's next in urban mobility and technology. With the USDOT SCC complete and other efforts from the City, COTA, DriveOhio, The Columbus Partnership, MORPC and others established and gaining momentum, regional leaders continue to embrace new concepts and innovation. Community leaders have rallied around Columbus' emergence as a smart city. Policymakers have been inspired to create further change and new collaborative initiatives have emerged.

Innovation continues throughout the regional mobility ecosystem**.** Some programs build upon the infrastructure assets and knowledge directly created by the Smart Columbus projects. Other partnerships will create new programs, introduce new solutions and promote adoption of new mobility technologies. The following sections summarize the exciting initiatives underway throughout the region.

ES-5.4.2.1 Autonomous Vehicles

- **Automated Driving System (ADS)** and **Advanced Transportation and Congestion Management Technologies Deployment (ATCMTD) Grants** – Since the deployment of Smart Circuit and the Linden LEAP, DriveOhio won two grants to advance vehicle automation in the state and region. The first, an Automated Driving Systems grant in 2019 with a focus on "Deploying Automated Technologies Anywhere" (DATA) focused on rural environments and cooperative automation, and the second, a grant in 2020 for truck automation on I-70 between Indiana and Ohio.

- **SMARTCenter** – In July 2019, the Transportation Research Center in East Liberty, Ohio opened its SMARTCenter (Smart Mobility Advanced Research Test Center), a dedicated 540-acre AV and connected vehicle test area within the immense 4,500-acre TRC proving grounds. This new $45 million investment established TRC as North America's largest AV test facility.

ES-5.4.2.2 Connected Vehicles

- **33 Smart Mobility Corridor** – A $5.9 million demonstration grant from USDOT helped initiate this project, which was led by DriveOhio, the City of Marysville, Union County, and the City of Dublin. This project created a 35-mile corridor with redundant fiber network and 87 dedicated short-range communications (DSRC) devices along US-33 through Marysville and Dublin. Both Columbus and Dublin are planning on extending the fiber network and DSRC installations to the point where they meet in Northwest Columbus to create an expanded, interoperable connected vehicle environment. The 33 Smart Mobility Corridor partners were recently selected for an opportunity with the Institute of Transportation Engineers (ITE) to conduct interoperability testing among these deployments.
- **Vision Zero** – Joining a national road safety initiative, Columbus' Vision Zero Columbus Action Plan lays out a strategy to pursue the goal of zero fatalities and serious injuries from crashes on city streets. The Action Plan identifies a High Injury Network of city streets that have a higher density of fatal or serious crashes where injuries and fatalities frequently involve vulnerable road users such as pedestrians, bicyclists and motorcyclists. With the current CVE infrastructure remaining in operation (and licensed by the Federal Communications Commission for the foreseeable future), this infrastructure and potential future expansion of the CVE network can help reduce crashes and improve safety for all roadway users.

ES-5.4.2.3 Electric Vehicles

- **Statewide Charging Strategy** – In 2020, DriveOhio developed and documented a statewide approach to EV charging and published an EV strategic plan. The purpose of this plan is to assess needs for electric vehicle charging, primarily along Ohio's highway corridors. The report identifies DC Fast Charging gaps in Interstate, U.S. highway and state route corridors, and identifies options to fill them.

ES-5.4.2.4 Shared Mobility

- **LinkUS –** LinkUS is Central Ohio's transformational and comprehensive prosperity and mobility initiative unveiled in June 2020, and is jointly led by the City, COTA, MORPC and Franklin County, with private sector and neighborhood partners. LinkUS is intended to serve as an umbrella program for all mobility implementation efforts in the region. The innovative approach will include high capacity and advanced rapid transit, bikeways, green space, pedestrian improvements, and focusing land development along major roadway corridors throughout Central Ohio. The initiative is actively seeking solutions to address traffic congestion, provide new mobility options, expand access to opportunities, and promote equity and economic vitality along key regional growth corridors. Projects such as SMH, MMTPA and CVE provide examples for such solutions and hold potential to contribute to what will be deployed through this promising initiative.
- Growth of the Shared Mobility Ecosystem – The number of mobility providers serving Columbus has expanded greatly during the past five years. Through active attraction efforts, Columbus introduced Zipcar, Chariot, Bird, Lime, Spin scooter and bike-sharing services to the market and fostered the foundation of homegrown startups EmpowerBus and SHARE Mobility.[9]

[9] https://sharemobility.com/

ES-5.5. Intelligent Mobility

- **COTA Fare Management System Upgrade** – In summer 2020, COTA initiated procurement of a new fare management system. In working on the MMTPA and CPS project requirements at the start of the Smart Columbus Program, COTA's existing fare system was a constraint that was difficult to accommodate into the user needs and requirements. However, the COVID-19 pandemic placed an increased priority on contactless payment for COTA. With this concern, as well as a desire for other improvements to fare management, COTA approved a contract with Masabi in October 2020, which is expected to be completed in 2021, and integrated with Pivot. This new solution will be account-based, multimodal, and will use an open architecture that is scalable to support growth, and capable of accepting a variety of payment types, in alignment with the original concept for the MMTPA.
- **COTA Traffic Management and Predictive Analytics Artificial Intelligence System** – In December 2020, COTA announced this first-of-its-kind project, which will improve traffic safety and reduce travel time for transit users across 13 central Ohio counties through a cloud-based connected mobility platform owned and operated by Waycare Technologies. The project is made possible by a $1.7 million Integrated Mobility Innovation Demonstration Research Grant awarded by USDOT to COTA and 13 additional partners. The system will be the largest of its kind in the country and the first involving public transit agencies.

ES-5.6. Conclusion

A key tenet of the Smart Columbus Program was managing in an agile and adaptable way, which allowed the program to plan and react to changing staff, partners, priorities and technology capabilities. A majority of the eight projects will move ahead in some form or fashion. The City is proud that, even though projects were removed from the original 15-project portfolio, many were implemented through other means. Even for projects that are not continuing, the knowledge and lessons that were learned have helped to increase awareness of emerging technologies and their benefits to all residents in Columbus. Managing stakeholder expectations and understanding the importance of communications was a key activity in Columbus' ability to mitigate risk and improve both awareness and technology adoption.

Ultimately the City used the Smart Columbus Program as a springboard to innovation. More importantly, the program empowered residents to live their best lives, as demonstrated by several important and quantifiable results. A few of the many great examples are the MAPCD project empowering individuals to travel independently for the first time, making mobility options more accessible for the Linden community through the construction of the SMHs in the neighborhood, enabling to reserve and pay for parking in advance (and check the likelihood of finding an on-street space) through the ParkColumbus app, and the CVE project training local automotive shops on the installation, use and operation of connected vehicle technology. These examples are among the many that are highlighted throughout this report and show the community impact of the program, both big and small.

Projects from this portfolio will be sustained to continue to serve the mobility needs of Columbus residents, and the partnerships and project management methodologies honed through the program will benefit the community for years to come. Through the implementation of the SCC, the projects have created short- and long-term impacts for the Columbus community and created a replicable playbook that other cities may build upon to have similar effects across the nation. The Smart Columbus Program has also added to the knowledge base for smart cities projects, advancing the development of multimodal and MAPCD-type projects, spurring research into the benefits of prenatal trip assistance, and helping advance vehicle automation and connected vehicle technology.

Chapter 1. Introduction

The U.S. Department of Transportation (USDOT) announced the Smart City Challenge (SCC) in late 2015. The challenge solicited proposals from mid-sized cities and was designed to accelerate the deployment and demonstration of smart city concepts. USDOT sought to "demonstrate how advanced data and intelligent transportation systems (ITS) technologies and applications can be used to reduce congestion, keep travelers safe, protect the environment, respond to climate change, connect underserved communities, and support economic vitality."[10]

Since the time of application, Columbus' approach to the SCC has been branded the Smart Columbus Program. The Smart Columbus Program is a compilation of transportation, mobility and data projects developed to improve access to jobs, enhance the visitor experience, stimulate economic prosperity, better connect residents to safe and reliable transportation and support the efficient movement of people and goods through environmentally sustainable practices. The projects were developed to independently address several transportation challenges related to safety and mobility in Columbus.

Ultimately, the Smart Columbus Program was redesigned to integrate the different project elements into a holistic solution designed and deployed to demonstrate how an intelligent transportation system, focused on equitable access to transportation, can empower all residents to live their best lives.

The Final Report provides a summary of how the Smart Columbus Program and its projects were executed, identifying the purpose, objectives and findings for each. This document serves as a summary of what the program accomplished, and the benefits, successes and opportunities for both the program as a whole and for each project element. It is hoped that others will find this report useful in implementing their own smart city programs.

The primary goals and expectations of the Final Report, which is a required deliverable in the City's Cooperative Agreement with USDOT (Task J), are as follows:

- Highlight the deployment and operational costs of the project and compare with the benefits and cost savings the project provides.
- Summarize the ways the City of Columbus addressed its challenges and met the expectations defined in the City's Smart City vision, including:
  - Summarize how the program helped improve safety, mobility, sustainability, access to opportunity, economic vitality and/or reduction in environmental impact
  - Explain the City's holistic approach to addressing transportation challenges by deploying projects and strategies consistent with the USDOT 12 vision elements
  - Highlight lessons learned and recommendations for other locations considering implementation of similar solutions

[10] *USDOT Notice of Funding Opportunity Number DTFH6116RA00002 "Beyond Traffic: The Smart City Challenge". Issue date: 12/7/2015.*

1.1. REPORT OVERVIEW

The final report includes 13 chapters which summarize the following topics:

- **Chapter 1. Introduction –** Provides a high-level summary and an overview of the Smart Columbus Program, and the SCC
- **Chapter 2. Smart Columbus Program Overview –** Discusses the program path by year, highlights the program scope, and includes a description of the Cooperative Agreement task structure
- **Chapter 3. Program Management and Delivery Summary –** Discusses the structure for delivering the Cooperative Agreement requirements, and closely aligns with its required tasks, including:
  - Program management organization and approach (Task A)
  - Program approach to data management and privacy (Task D)
  - Location and overview of data collected in the program (Task E)
  - Program approach to safety management and protection of human research subjects (Task F)
  - Summary and highlights of program communications strategies and tactics and stakeholders (Task G)
- **Chapter 4. Performance Measurement Findings –** Provides information on how the program satisfied the Cooperative Agreement's Task C by providing a summary of the performance measurement results from the perspectives of safety, mobility, environment, opportunity, agency efficiency and customer satisfaction
- **Chapter 5. Conclusions, Challenges, Lessons Learned and Recommendations –** Includes a summary of how the project addressed city challenges and met the original expectations defined in the Smart City vision, as well as recommendations for other early deployment locations

The remainder of the report includes a chapter for each project, providing an overview, deployment summary (including systems engineering, which is Task B of the Cooperative Agreement), project costs, project evolution, conclusions, lessons learned and recommendations.

- **Chapter 6. Smart Columbus Operating System**
- **Chapter 7. Connected Vehicle Environment**
- **Chapter 8. Multimodal Trip Planning Application**
- **Chapter 9. Smart Mobility Hubs**
- **Chapter 10. Mobility Assistance for People with Cognitive Disabilities**
- **Chapter 11. Prenatal Trip Assistance**
- **Chapter 12. Event Parking Management**
- **Chapter 13. Connected Electric Autonomous Vehicles**

The Final Report also includes a set of appendices:

- **Appendix A. Acronyms –** Lists the acronyms used throughout the Final Report.
- **Appendix B. References –** Lists the documents on the Smart Columbus website that reflect all deliverables under the Cooperative Agreement for both the program and the projects.
- **Appendix C. Agreements –** Provides a listing by project of all the agreements and MOUs that were necessary to execute the program.

- **Appendix D. Public Outreach Materials –** Lists the materials prepared by the communications team to support project delivery.
- **Appendix E. Program Results from The Ohio State University –** Provides the details of additional program analysis by The Ohio State University (OSU) that was conducted to assess the impact of the Smart Columbus projects. Highlights of this analysis are included in **Chapter 4**, but this Appendix provides the full research results which include an economic, accessibility and housing analysis.

1.2. PROGRAM BACKGROUND

1.2.1. USDOT Smart City Challenge

In December 2015, USDOT launched the SCC, asking mid-sized cities across America to develop ideas for an integrated, first-of-its-kind smart transportation system that uses technology to help people and goods move more quickly, cheaply and efficiently.

By challenging American cities to use emerging transportation technologies to address their most pressing problems, USDOT aimed to spread innovation through a mixture of competition, collaboration, and experimentation. The SCC called on cities to do more than merely introduce new technologies onto city streets. It called on them to boldly envision new solutions that would change the face of urban transportation by closing the gap between rich and poor, capturing the needs of both young and old, and bridging the digital divide through smart design so that the future of transportation meets the needs of all Columbus residents.

Columbus competed against 77 cities and won the SCC in 2016, which included a $40 million award from USDOT. The Smart Columbus Program aimed to improve quality of life, drive growth in the economy, provide better access to jobs and ladders of opportunity, become a world-class logistics leader, and foster sustainability. With the USDOT funds, as well as monetary and in-kind contributions from a number of cost-share and key leveraged partners, the City demonstrated how advanced technologies can be integrated into other operational areas within the city, using advancements in ITS, connected vehicles (CVs), automated vehicles (AVs) and electric vehicles (EVs), while integrating data from various sectors and sources to power these technologies, and leveraging the new information they provide. Community and customer engagement were present throughout the program, driving the requirements and outcomes for each project. This end-user engagement reinforced the idea that the residents of Columbus are ultimately the owners and co-creators of the Smart Columbus Program and should be the main beneficiaries. Columbus defined what it means to be a "smart city," and serves as a model for other cities wishing to fully integrate the innovative technologies and community development that are part of the Smart Columbus Program.

1.2.2. Smart Columbus Overview

The Smart Columbus Program included eight projects grouped into three overarching themes: Enabling Technologies, Enhanced Human Services and Emerging Technologies. The three themes are defined below:

- **Enabling Technologies –** Leverage today's technology in new and innovative ways to greatly enhance the safety and mobility of transportation infrastructure. These advanced technologies are building a rich data stream of transportation and mobility information, creating high-quality data for traffic management and safety purposes. The Smart Columbus Connected Vehicle Environment (CVE) project deployed CV infrastructure and onboard vehicle equipment to enhance the safety and mobility of vehicle operators, improve pedestrian safety in school zones, reduce response time for emergency vehicles, and reduce idling time for freight vehicles.

- **Enhanced Human Services –** Meet human needs through the application of technology that focuses on prevention as well as remediation of problems and maintains a commitment to improving the overall quality of life of users of the technology-based solutions. These projects, listed in **Figure 1-1**, create opportunity by providing improved access to jobs, health care and events.
- **Emerging Technologies –** New technologies that are in development or will be developed over the next five to 10 years will substantially alter the business and social environment. Columbus chose to focus on CVs, AVs and EVs, which collectively comprise one of the highest-potential Emerging Technologies. The Smart Columbus Connected Electric Autonomous Vehicles (CEAV) project demonstrated potential solutions to address and mitigate future transportation and data collection challenges for this technology.

Figure 1-1 shows the final portfolio of eight projects that were demonstrated. Seven of the eight projects fall under one of the three themes, with the Smart Columbus Operating System (SCOS) acting as the point of data integration for all projects. The SCOS – which is anticipated to continue to operate after the SCC demonstration is completed – collects, manages and provides the data needed for all current and future smart city projects. The eight projects are outlined below:

- **Smart Columbus Operating System (SCOS) –** The SCOS is a platform designed for big data, analytics, and complex data exchange. It collects, manages, and provides over 2,000 datasets, including data from each of the Smart Columbus projects, and provides a means for multi-user access to aggregate, fuse, and consume data.
- **Connected Vehicle Environment (CVE) –** This project deployed technology in over 1,000 vehicles and at 85 intersections across four corridors in the city. These devices enable vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communication, supporting safety and mobility applications that provide alerts to drivers, coordinate signal priority and preemption at intersections for priority vehicles, and provide data to agency users from the City and COTA.
- **Multimodal Trip Planning Application (MMTPA) –** The MMTPA project created a website and smartphone app, branded Pivot, that allows travelers to request and view multiple trip itineraries and make reservations for shared-use transportation options such as bike-sharing, ride-hailing and scooter-sharing.
- **Mobility Assistance for People with Cognitive Disabilities (MAPCD) –** The MAPCD project demonstrated an innovative smartphone app for people with cognitive disabilities to increase independent travel on the fixed-route bus system. The app included a highly accurate, turn-by-turn navigator designed to be sufficiently intuitive such that older adults and individuals with disabilities including the cognitively disabled could travel independently.
- **Prenatal Trip Assistance (PTA) –** The City developed a system for providing flexible, reliable, two-way transportation to pregnant individuals scheduled through a smartphone app, website or a call center. The project used Medicaid Managed Care Organizations (MCO) to provide non-emergency medical transportation services.
- **Smart Mobility Hubs (SMH) –** This project consolidated transportation resources and offered access to comprehensive trip planning tools at six designated locations. These hubs are primarily located adjacent to existing transit center facilities and provide physical space for the consolidation of services such as bike/scooter-share, car share, and ride-hailing. Interactive kiosks and public Wi-Fi are available to the traveler to view real-time travel information and to create and book multimodal trips via the Pivot app.

- **Event Parking Management (EPM)** – EPM expanded the features of the City's ParkColumbus app and developed a website to integrate parking information from City owned parking meters and multiple parking facilities into a single availability and reservation services solution. This allows travelers to search for and reserve parking in advance or on the go. More direct routing of travelers during large events is expected to reduce congestion during those times. The solution also identifies the current projected on-street parking availability near users' target destinations using predictive analytics.
- **Connected Electric Autonomous Vehicles (CEAV) –** This project deployed automated shuttles that operated in a mixed-traffic environment interacting with other vehicles, bicyclists, and pedestrians. There were two demonstrations conducted during the project, one downtown and one in the Linden community.

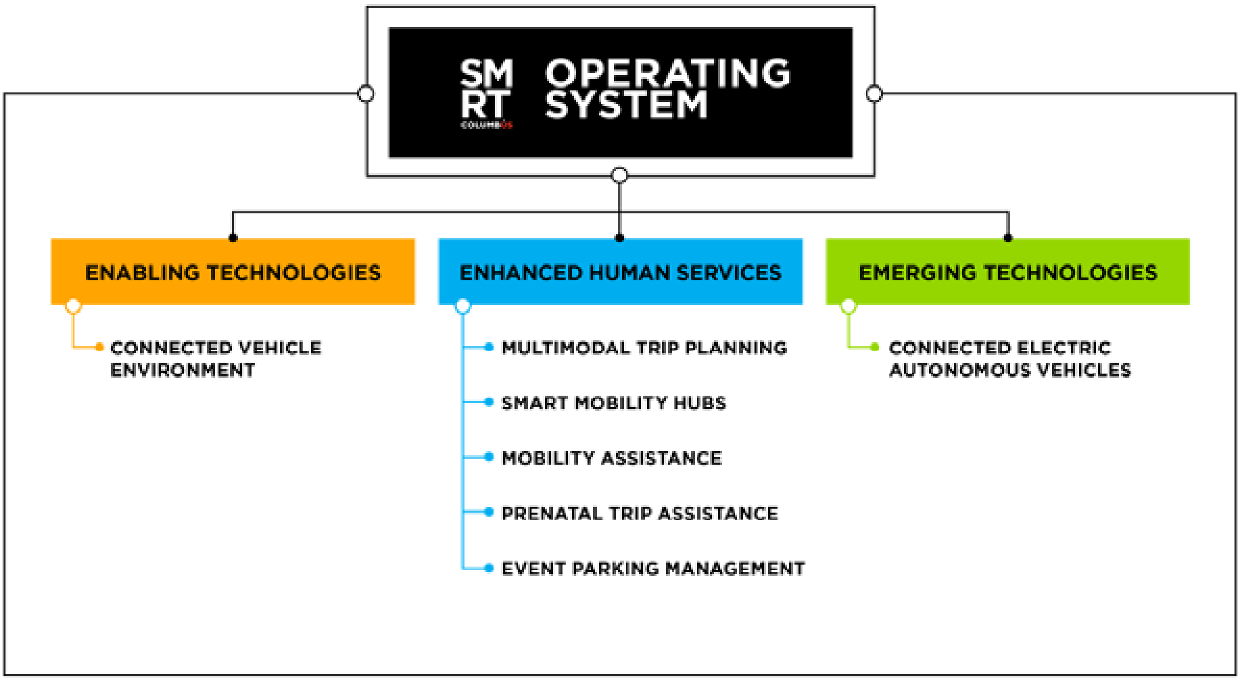

Figure 1-1: Smart Columbus Projects

Source: City of Columbus

1.2.3. Smart Columbus Outcomes

The City of Columbus' guiding smart city principle is that mobility is the great equalizer: equitable access to transportation and mobility solutions opens doors to jobs, health care, education, and other opportunities that empower residents. The City is attempting to shift the transportation paradigm to ensure all residents can traverse Columbus in a safe and efficient manner of their choice.

The specific desired outcomes of the Smart Columbus Program included:

- **Improve Safety –** Create safer streets where vehicles, cyclists and pedestrians are less likely to be involved in accidents.
- **Enhance Mobility –** Make traversing and parking in Columbus as efficient and convenient as possible.

- **Enhance Access to Opportunities and Services –** Make multimodal transportation options and the ability to access them equitably available to all residents, especially those who have difficulties traveling to health care, jobs, school and training.
- **Reduce Environmental Impact –** Reduce the negative impact transportation has on the environment by embracing multimodal options, and otherwise encouraging more-efficient travel patterns and reduced emissions.
- **Agency Efficiency –** Improve the ability of government, transportation, and community agencies to access real-time data, streamline internal processes to improve communications and information sharing, and make internal agency operations more efficient.
- **Customer Satisfaction –** Provide mobility choices and services that users feel improve their quality of life.

Figure 1-2 shows the Smart Columbus vision, mission and outcomes.

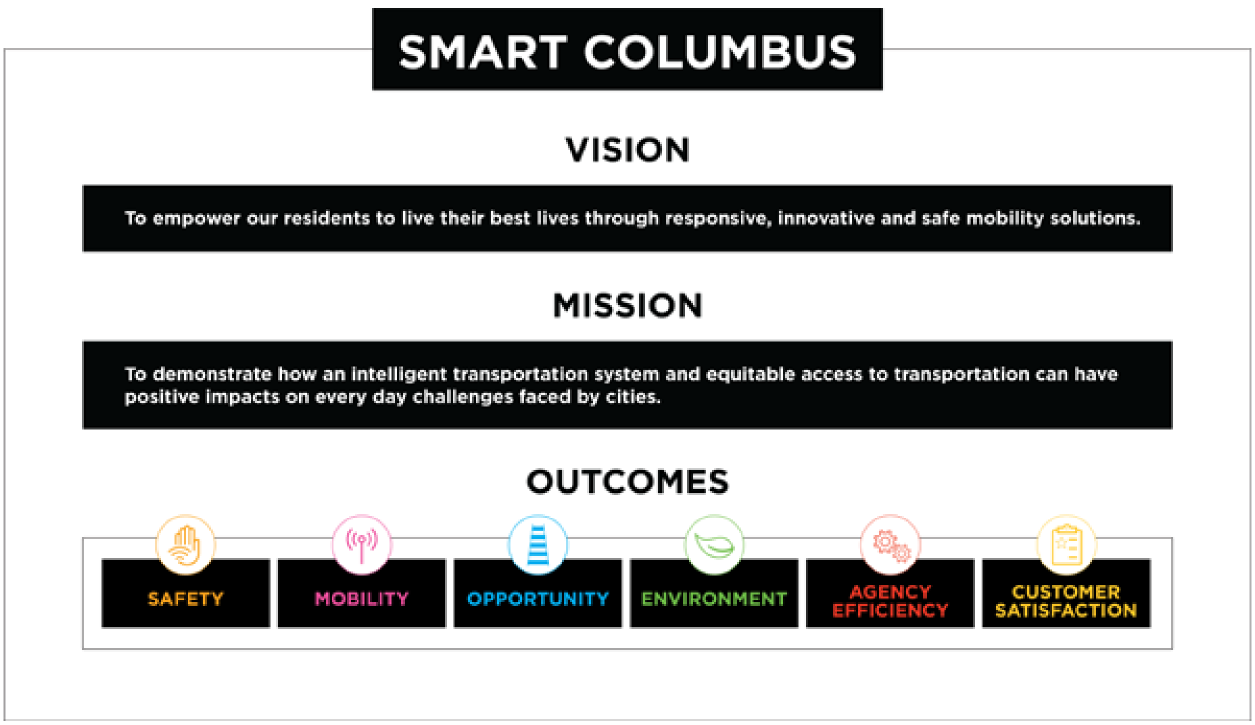

Figure 1-2: Smart Columbus Vision, Mission and Outcomes

Source: City of Columbus

Chapter 2. Smart Columbus Program Overview

This chapter provides an overview of Smart Columbus Program activities from 2016 to 2021. It briefly summarizes the technical approach to deploying the program; provides highlights for each year of the program's Cooperative Agreement; and concludes with an overview of how the program demonstrated the 12 Vision Elements for a smart city demonstration that the USDOT's Smart City Challenge (SCC) notice identified. Applicants were encouraged to consider these 12 elements in developing ideas for their cities' approaches for a smart city demonstration that would address real-world issues and challenges facing residents and cities.

Figure 2-1 shows these Vision Elements, which build upon USDOT's Fiscal Year (FY) 2014-2018 Strategic Plan[11] and DOT Strategic Plan for FY 2018-2022.[12]

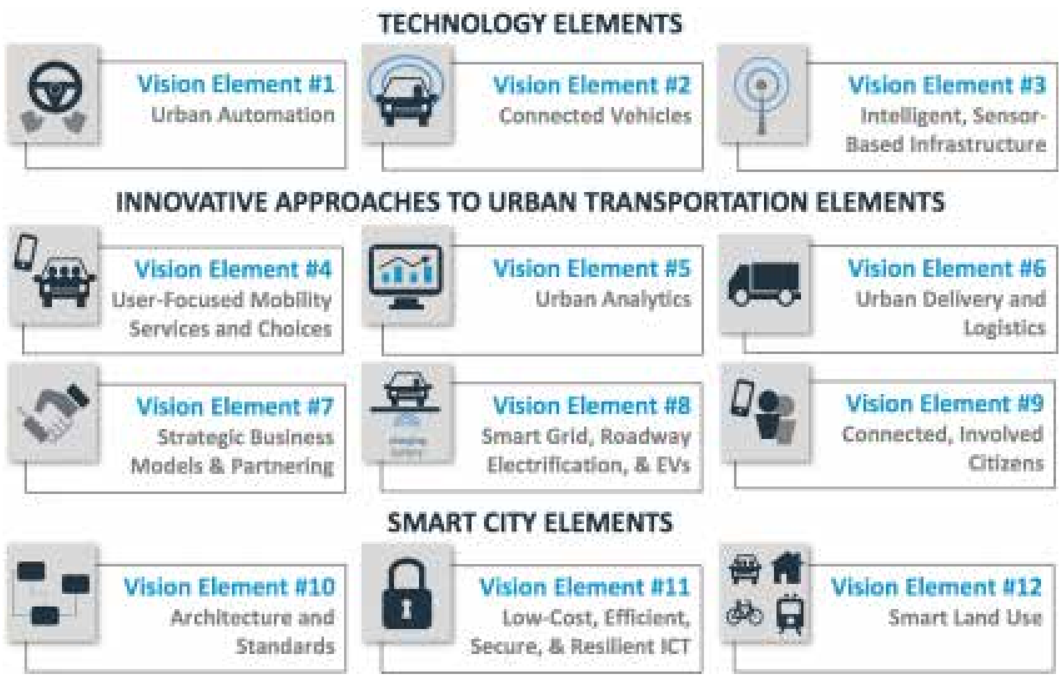

Figure 2-1: USDOT 12 Smart City Vision Elements

Source: USDOT

11 https://www.transportation.gov/sites/dot.gov/files/docs/2014-2018-strategic-plan_0.pdf

12 https://www.transportation.gov/sites/dot.gov/files/docs/mission/administrations/office-policy/304866/dot-strategic-plan-fy2018-2022508.pdf

The City's original application and portfolio identified the following four districts:

- **Downtown –** The Columbus central business district
- **Residential –** The Linden neighborhood, a relatively low-income neighborhood suffering from high unemployment, high crime, and an infant mortality rate more than twice that of the county average
- **Logistics –** Rickenbacker area, which includes a rail yard, a freight airport, and an estimated 80 million square feet of warehouse and distribution space
- **Commercial –** Easton Town Center, a large, vibrant, mixed-use development, which includes an outdoor "lifestyle" mall, other nearby commercial and office space, a hotel, and multifamily residential

Figure 2-2: Proposed Program Portfolio Organization

Source: City of Columbus

THE CITY OF COLUMBUS ANDREW J. GINTHER, MAYOR

The City of Columbus Cooperative Agreement with USDOT set the stage for the steps to perform the smart city demonstration. It outlined the following ten tasks intended to provide not only the systems engineering framework for the individual projects, but also other foundational elements necessary to demonstrate, quantify and evaluate the impact of the program.

- Task A: Program Management
- Task B: Systems Engineering Approach
- Task C: Performance Measurement
- Task D: Data Privacy Requirements
- Task E: Data Management and Support for Independent Evaluation
- Task F: Safety Management and Safety Assurance
- Task G: Communications and Outreach
- Task H: International Collaboration
- Task I: Participation in Relevant Intelligent Transportation Systems (ITS) Architecture and Standards Development Efforts
- Task J: Interim and Final Reporting

2.1. SYSTEMS ENGINEERING REQUIREMENTS

Systems engineering is the process of how projects come to fruition. At its core, systems engineering takes a project through its life cycle, from concept through to its design and deployment, and ends at its operations and maintenance phase, or retirement. With large scale or expensive projects, such as the ones that the SCC called for, it is important to plan out the steps and needs of a project to minimize waste in time and resources. The Smart Columbus Program used four types of systems engineering methods: Off-the-Shelf, V-Model, Agile and Hybrid (in which projects began as V-Model and pivoted to Agile during the decomposition and definition process).

V-Model, also known as Waterfall, is the traditional approach and lends itself nicely to projects with a construction component. As shown in **Figure 2-3**, the steps toward project completion follow a linear path, with each phase building onto the next. Early stages – especially the Concept of Operations and System Requirements – are stakeholder-driven, whereby the project team conducts extensive discovery and engagement to gather and document user needs and requirements for the system, which are then used as reference points through the rest of the development and testing of the project.

The center of the V-Model diagram shows how the systems engineering process first examines the “big picture” (Concept of Operations), before defining the project (the “system”). The process then moves to development of smaller components of the project (subsystems and units). After initial development, or coding in the case of software, the process starts testing and integration. Following the V, this begins with testing for the smallest components (units), which are then integrated into subsystems, which are in turn tested before integrating and validating the overall project.

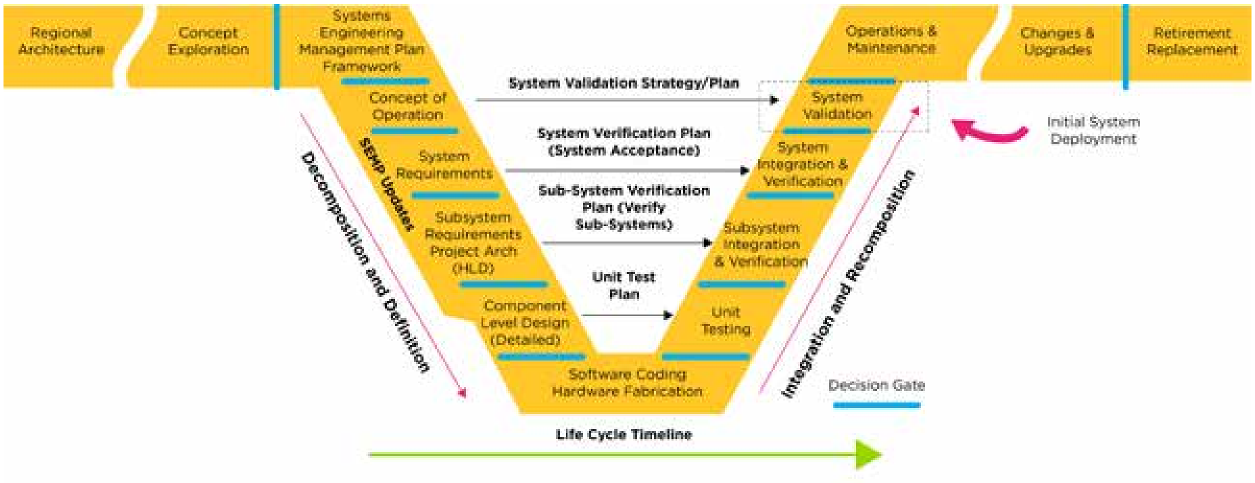

Figure 2-3: V-Model Diagram

Source: City of Columbus

Agile is an iterative development process, best suited for software-based projects. After the initial needs and basic requirements are determined, the development takes place in short time frames called “sprints.” These sprints are done to allow for a “fail fast, recover quickly” style of development. Regular “scrum” meetings are a hallmark of this methodology, and something that was used at both the program and project level. These regular meetings engaged all members of the project team (City, vendors, consultants and partners) as a means of guiding teams in the iterative and incremental delivery of the project. Scrum meetings enabled the project teams to respond rapidly, efficiently, and effectively to change.

Unlike V-Model, where testing is done after the initial product is completed, testing is continuous as more features are developed and released in the sprints. Software exists in a perpetually changing environment because it is unrealistic to set firm expectations of a final product for something that will take years to develop. User stories replace user needs and system requirements and represent the smallest unit of work; it is a goal for the product expressed from the user’s point of view as opposed to a feature.

Agile also emphasizes early delivery of a minimum viable product, which is an early version of the product that contains the minimal functionality and features to be usable by early customers. This way, these customers can then provide feedback for future product development. **Figure 2-4** depicts the Agile process.

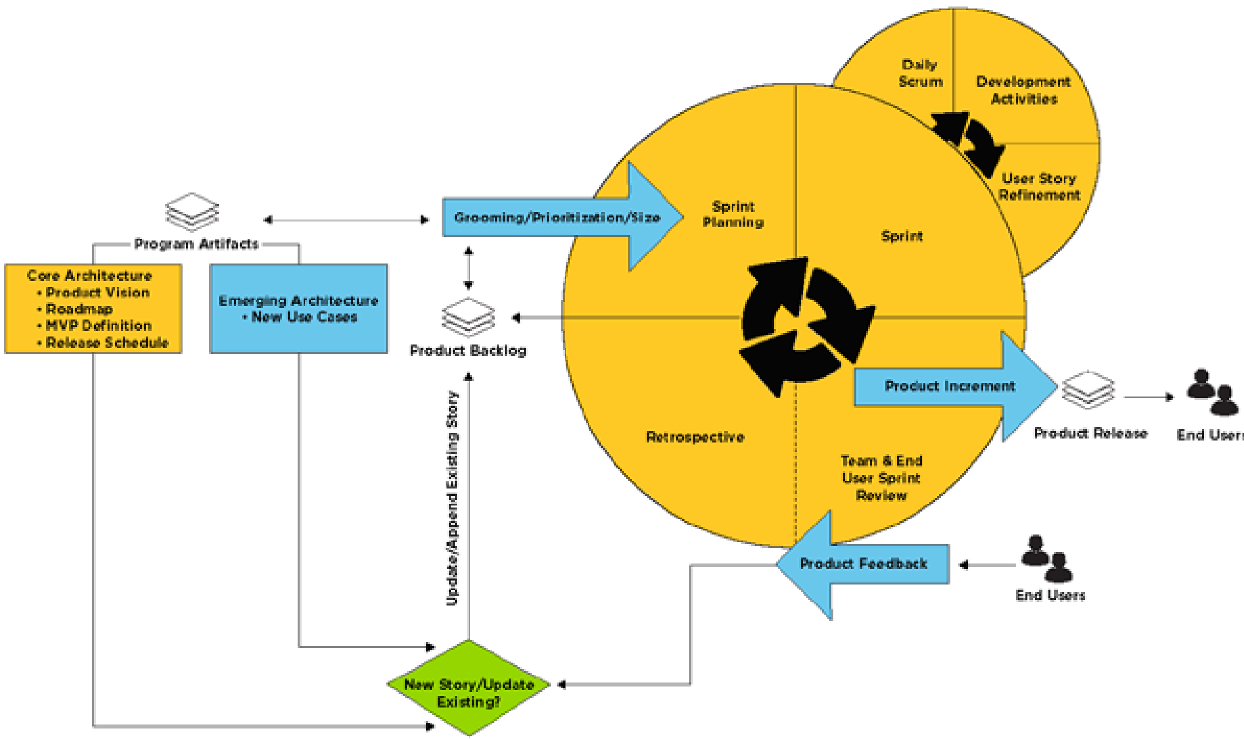

Figure 2-4: Agile Systems Engineering Process

Source: The City of Columbus

Due to the nature of some projects, the City decided that a combined approach of V-Model and Agile – called **Hybrid** – would be most appropriate. In these projects, much of the documentation required of the V-Model process was completed but the development phase was broken up into sprints because of its heavy use of software.

Off-the-shelf projects were procured products that the City purchased and integrated into existing operations, as these products were already fully or near fully meeting the identified needs of the project. In some cases, minimum customization was needed to fulfill the objectives of the project. For these projects, the City conducted a trade study, which documents user needs and evaluates the product's ability to meet them. The City's project management team produced other documentation for this process, including defining interfaces for the product to connect to existing systems, and validating the product's satisfaction of user needs in a test plan and results document.

2.2. PROGRAM PATH BY YEAR

The Smart Columbus Program went through several changes over the nearly five-year course of the award period to adapt to challenges and new information learned during the project. These changes are described by year below. Note that these years correspond roughly to federal FYs, with the first year covering August 2016, when the Cooperative Agreement began, to September 2017.

2.2.1. Year 1: Initialization and Engagement

After being named the SCC winner in June 2016, the City of Columbus formed a Smart Columbus Program Management Office (PMO) made up of City employees. The PMO set up an organization that could execute the City's and USDOT's vision through the multiyear Cooperative Agreement. The PMO created a structure with the authority and skillset to implement the 15 projects proposed in the winning application. Flexibility was key, as the City reallocated resources throughout the program to better fulfill its responsibilities and position the program for successful implementation.

In Year 1, the PMO, with USDOT guidance, developed a comprehensive approach for program management and systems engineering, anchored by a structured stakeholder engagement process (which included public engagement) to inform project user needs and enhance the likelihood that demonstration projects would be adopted by end users. The team developed a communication and outreach plan that shaped the partner and vendor engagement strategy. This included establishing working groups made up of these partners and potential vendors to identify problem statements and user needs, define goals, roles, and responsibilities. The project teams conducted focus groups and interviews with these stakeholders to solicit user needs. Engagement with the Linden neighborhood began with the Linden Innovation sessions, a two-day workshop that helped identify the project needs for several projects. The role of the working groups is discussed in more detail in **Chapter 3.**

Figure 2-5: Smart Columbus Data Technical Working Group

Source: City of Columbus

The original framework clearly defined the functions required over the duration of the Cooperative Agreement. It also enabled the PMO and project teams to conduct "discovery" (information-gathering) with the many stakeholders who had contributed to the application process, as well as the potential end users for the solutions under consideration. This engagement was key in evaluating which projects held the most promise in terms of delivering benefits to the City and its communities.

While the original framework was envisioned as a cohesive program, it did not define where the connections and coordination points between projects needed to be during development and design. As the first year concluded, the PMO worked to streamline the projects and bring more clarity to the program and schedule. The PMO also added positions with a dedicated focus on delivering the Cooperative Agreement requirements, managing the program-level activities, and leading the various projects. The evolution of the PMO is discussed in more detail in **Chapter 3.**

Highlights from the first year included work associated with establishing communications, beginning the systems engineering process, and defining the Integrated Data Exchange, later known as the Smart Columbus Operating System (SCOS).

2.2.2. Year 2: Program Restructure and Systems Engineering

The demonstration encountered several challenges its first year, which encouraged further program changes and adaptations, and helped the City identify where to chart a better path forward. Inter-program communications – among and between the projects and the SCOS at its core – were front and center as a lesson learned for continued enhancement. At the beginning of Year 2, the PMO hosted a daylong strategy session at which the team evaluated the proposed portfolio of USDOT-funded projects. This session included key stakeholders including The Columbus Partnership, Central Ohio Transit Authority (COTA), The Ohio State University (OSU), CelebrateOne and the following City departments: Technology, Public Service and Neighborhoods. This process was used to evaluate the 15 proposed projects in the context of the expected outcomes established by USDOT and the original goals outlined by the City. The PMO also considered the end-user and stakeholder feedback gathered throughout the first year of the program through the systems engineering process.

The result of the workshop and the discovery sessions with stakeholders and users led to a more refined portfolio of nine projects. Knowing that becoming a smart city is anchored by open, integrated and holistic data, the City repositioned the SCOS as the backbone of the Smart Columbus project portfolio. The SCOS ingests data from the other projects, as well as other public and private datasets. It provides data analytics that will continue to power smart city projects into the future.

The original 15 projects were restructured into nine projects based on the consensus gained during a program realignment meeting held after the strategy session. Some projects were removed from the portfolio, others were consolidated, and one was added. The remaining projects were regrouped based on the three themes discussed in **Chapter 1 (Section 1.2.2):** Enabling Technologies, Enhanced Human Services and Emerging Technologies.

In coordination with USDOT, the Smart Columbus PMO removed the following projects from the portfolio:

- **Delivery Zone Assistance Application –** End-user research illustrated that delivery truck drivers would not find this application helpful.
- **Transit Collision Avoidance System –** The partner solution provider, Mobileye, was not a sustainable long-term solution for COTA, the proposed project owner. While COTA is interested in collision avoidance systems, this was not a viable solution due to the fact that the technology did not eliminate the type of crashes COTA was seeking to reduce.
- **Smart Streetlights –** These were removed from the portfolio because the Department of Utilities was scaling quickly and planning a more robust and strategic streetlight deployment.
- **Enhanced Permit Parking –** The concept of more efficient parking permits and enforcement strategies was incorporated into the Department of Public Service's Short North parking plan.

Additionally, the Smart Columbus PMO consolidated the following projects:

- **Oversized Vehicle Routing –** This project was folded into the SCOS because stakeholder discovery revealed the data-centric element of this project. The "user story" for this project (who would use it, and why they need it) indicated that the challenge being solved was really around providing information, and therefore was better suited for delivery as part of the SCOS.[13]
- **Interstate Truck Parking Availability –** This project also became part of the SCOS. As with Oversized Vehicle Routing, this was essentially an issue related to collection and visibility of data.[14]
- **Multimodal Trip Planning Application (MMTPA) and Common Payment System (CPS) –** These projects were combined into one project because they were envisioned as two technical components of one application.

Finally, the Smart Columbus PMO added one new project:

- **Prenatal Trip Assistance (PTA) –** With research provided by Sidewalk Labs, the Smart Columbus Program partnered with OSU researchers to develop and study a system to easily provide flexible, reliable, two-way transportation to medical visits for pregnant individuals on Medicaid.

Highlights of the second year included the restructuring of the PMO and updated definition of program themes and branding that was used for the rest of the demonstration. The PMO restructuring also resulted in not only the right "seats" being created within the City and their consultant teams, but also placing the right people in those seats. With the restructured program and staff, the team quickly updated guiding documents including the Project Management Plan and Systems Engineering Management Plan (SEMP), the latter of which solidified the systems engineering methodology.

The revised SEMP identified projects that were to follow the V-Model approach, and those projects best completed under an Agile or Hybrid approach. Others were executed through the purchase of an off-the-shelf product customized and integrated into the program. With the revisions to the PMO and restructuring of the portfolio, the Cooperative Agreement was amended in September 2018 to extend the period of performance by nine months through May 2021.

Perhaps most importantly, with the significance of the SCOS as a central element of the program structure, the development for that team continued in its Agile development cycle, and concluded calendar year 2017 with the minimum viable product delivery of the SCOS online data portal in December. With the new program management and systems engineering methodology documented in the SEMP, the remainder of Year 2 focused on completing the first few systems engineering deliverables for the eight projects (exclusive of the SCOS). The City also released its first procurement in January 2018 to seek new consultant support for the SCOS. Pillar Technology (now Accenture) was selected in March, and onboarding was complete in May 2018. The new team sought to continue the development of the SCOS using the "DevOps" approach.[15] To support the management of data being brought into the SCOS, the PMO also completed initial drafts of the data management and data privacy plans, which were developed with the assistance of the working groups, implemented in collaboration with the SCOS team, and carried forward to the project teams and vendors that ultimately supported them through the procurement process.

A final highlight of the second year was the opening of the Smart Columbus Experience Center (see **Figure 2-6**) in June 2018.[16] The Experience Center gave the Smart Columbus Program a touchpoint with

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13 *More information available at: https://www.smartcolumbusos.com/data-stories/how-might-bridge-data-help-drivers-avoid-can-opener-accidents*

14 *Interstate truck parking data is available at: https://discovery.smartcolumbusos.com/dataset/mid_america_assc_trnsprt_ofls/ab3fdb4d_9794_4839_b49b_e65e8458a5f3*

15 *https://aws.amazon.com/devops/what-is-devops/*

16 *https://smart.columbus.gov/get-involved/experience-center*

the community, while also co-locating the office for the PMO with key partners. Located on the Scioto Mile in downtown Columbus, it served as one of the stops on the first Connected Electric Autonomous Vehicles (CEAV) project deployment, the Smart Circuit. It hosted many electric vehicle (EV) demonstrations and offered test drives and tours of these vehicles. It also housed IKE brand interactive kiosks (IKs) similar to those deployed at Smart Mobility Hubs (SMHs) and featured numerous exhibits about smart mobility and intelligent transportation.

Figure 2-6: Smart Columbus Experience Center

Source: City of Columbus

2.2.3. Year 3: Procurement and Development

The PMO established momentum with the systems engineering efforts that continued into Year 3. Many projects had completed the initial system concepts or trade studies. While systems engineering activity continued with requirements and design efforts, another critical activity of the third year was procuring the vendor support to develop what the project teams had designed.

In Year 3 of the program, the City initiated procurement for many projects after completing the system requirements. In the case of Agile or Hybrid projects, requests for proposal (RFPs) included defining requirements for vendors seeking to support the project.[17] **Table 2-1** summarizes the methodology, procurement schedule and selected vendor for all the projects in the portfolio.

[17] *Some trade study projects, such as the Mobility Assistance for People with Cognitive Disabilities (MAPCD) project, completed contracting with its selected vendors prior to Year 3. See **Table 2-1.***

Table 1: Summary of Project Procurement

Project	Systems Engineering Methodology	Procurement Dates	Vendor
Smart Columbus Operating System (SCOS)	Agile	01/2018 – 05/2018	Ÿ Pillar Technology (now Accenture)
Connected Vehicle Environment (CVE)	V-Model	05/2018 – 06/2019	Ÿ Roadside units (RSUs): Kapsch Ÿ Onboard units (OBUs): Siemens
Multimodal Trip Planning Application (MMTPA) and Common Payment System (CPS)	Hybrid	· 05/2018 – 12/2018 · 12/2018-3/2019	Ÿ MMTPA: MTech/ETCH Ÿ CPS: Siemens/Bytemark
Mobility Assistance for People with Cognitive Disabilities (MAPCD)	Off-the-Shelf	03/2018 – 06/2018	Ÿ AbleLink
Prenatal Trip Assistance (PTA)	Hybrid	06/2018 – 01/2019	Ÿ Kaizen Health
Smart Mobility Hubs (SMH)	V-Model	No procurement	Ÿ IKE Smart City/Orange Barrel Media Ÿ CoGo (Motivate/Lyft)
Event Parking Management (EPM)	Hybrid	No procurement	Ÿ ParkMobile
Connected Electric Autonomous Vehicles (CEAV)	Hybrid	Ÿ 5/2018 – 8/2018 Ÿ 11/2018 – 6/2019	Ÿ May Mobility Ÿ EasyMile

Source: City of Columbus

The City's procurement process involved the following three key elements:

- **Consultant/vendor selection –** Included RFP development and release, vendor response time, proposal evaluation and selection
- **Legislation –** Included drafting legislation for the PMO and City officials to approve before review and approval by City Council
- **Contracting –** Finalizing contract terms

This process can take approximately five months, although several Smart Columbus Program procurements were accelerated to maintain momentum and involve vendors in the project as systems engineering activities were wrapping up. The time to procure systems must be taken into consideration when implementing Smart Cities projects, as traditional processes within an agency may not keep up with the pace of emerging technologies.

The onboarding of vendors meant that development of projects could finally begin. For the first few projects "out of the gate" such as Mobility Assistance for People with Cognitive Disabilities (MAPCD), enhancements to the vendor's existing product were completed following customization recommendations identified during the systems engineering process and the project team's testing of the off-the-shelf solution.

For projects using the Hybrid approach, such as MMTPA and CPS, with the vendor on board, the vendor and City project team transitioned to the release-and-sprint cycles characterized by this methodology. In these cases, the teams began a regular cadence of develop, test, and implement for each component of the project.

For V-Model projects, system requirements were completed before the vendor selection process could begin. The selected vendors provided input and reviewed the development process to better inform system architecture and design activities, which set them up for success in their development and testing activities.

PROGRAM DELIVERABLES IN YEAR 3

Finalizing plans to demonstrate, quantify and evaluate the project impacts.

- Communications Plan
- Safety Management Plan
- System Architecture and Standards Plan (SASP)
- Performance Measurement Plan (PfMP)
- Demonstration Site Map and

With the program transitioning from planning and design to procurement, development, and even launch for a few of the early projects, there were many exciting milestones in Year 3.

First, as part of an effort to get the first automated shuttle on the streets, the City and other project partners including the Ohio Department of Transportation's (ODOT) DriveOhio, OSU, COTA and The Columbus Partnership, completed the first procurement for a self-driving shuttle as part of the CEAV project. Selecting May Mobility, the demonstration sought to inform and educate the community about the potential utility of this technology. May Mobility launched service on the Scioto Mile in December 2018.

The MAPCD project also completed its trade study and interface control document, onboarded AbleLink, and completed enhancements to their WayFinder product. With OSU leading recruiting and training, the MAPCD project launched with its participants in April 2019. PTA, again with OSU and CelebrateOne as key partners, also went live, launching the Rides4Baby application and began recruiting in June.

Another important Year 3 milestone was the launch of the Smart Columbus Operating System 2.0, which put the next version of the data management platform into production for all users.

These three projects were the first to enter demonstration and begin generating the data needed for performance measurement. Unfortunately, the systems engineering process also documented key needs and requirements that the truck platooning technology and key leveraged partner (Peloton) were unable to support. With the technology still firmly in the concept stage and Peloton unable to support a 12-month demonstration, the City recommended removing the truck platooning project from the program. USDOT accepted this change in May 2019 with an agreed-upon and corresponding budget reduction to the Cooperative Agreement.

2.2.4. Year 4: Testing and Demonstration

Year 4 was divided at the halfway point by the onset of COVID-19.

The first half of Year 4 began with momentum and enthusiasm, as most projects were actively making progress on development and testing. All projects that had not yet launched were intended to launch by July 2020. A big highlight of the first half of Year 4 was the approval by the National Highway Traffic Safety Administration (NHTSA) to test and operate the EasyMile shuttle on the Linden LEAP service for the second procurement of the CEAV. The Linden LEAP vehicles arrived in Columbus in December 2019, and much of January was spent testing and preparing for launch, which occurred on February 4, 2020. The pandemic hindered the program's momentum, introducing new risks and making existing risks harder to mitigate.

A major hallmark of the second half of Year 4 was the program and project teams' resilience and determination to make progress, implement mitigations and make decisions that all served the common goal of launching these impactful community projects, despite the challenges presented by the global pandemic.

Year 4 ended with the PMO finalizing the mitigations for new and altered risks, and clearly defining remaining activities and schedule. Major milestones included the launch of CVE onboard equipment installations, completing RSU installations, and launching private participant recruiting to great success.

Although the demonstration period had been extended to May 2021 in Year 2 to accommodate delays with program initialization and restructuring, the fourth year of the demonstration was still expected to be the time when all projects that had not yet launched would enter demonstration. All vendors were contracted, and for those projects that had an infrastructure element (CVE, SMH and CEAV), construction and installation was completed before testing began. Installation of infrastructure for CEAV and SMH began in November 2019 and concluded in early 2020, while CVE system installation also began in November but continued through July 2020 due to the size and scope of the corridor. The software-related projects including MMTPA, CPS and Event Parking Management (EPM) continued their Agile development processes, with testing occurring at the end of each release.

A major focus in Year 4 was the completion of the enterprise elements of each project: the enterprise architecture specifies all parties, which defines the relationships, roles and responsibilities with respect to each project's development, implementation, testing, operations and maintenance. As shown in **Appendix C**, nearly all of the projects required agreements to be put into place to adequately describe and finalize data collection, participation, terms of use, development and many other activities among the City and other project stakeholders. This effort began at the end of Year 3, with the project teams beginning to outline the agreements that were necessary and to draft, circulate and discuss these agreements (for all projects, with all stakeholders) over many months, an activity that continued into Year 4. This activity was able to continue largely in concert with the project development and testing. For certain projects and stakeholders, the agreement process was relatively straightforward, while for others (for example, the mobility providers whose participation was critical for MMTPA, CPS and SMH), it was a much lengthier process. **Appendix C** contains a list of all agreements by project. Please note, a complete description of the roles, relationships and agreements necessary to complete each project are contained in the Smart Columbus System Architecture and Standards Plan deliverable which can be found on the program website.

In March 2020, the COVID-19 pandemic hit, and in a matter of days, the PMO and its vendor and consultant staff transitioned to working remotely. Immediate impacts included the delayed launch of the SMH project, which had been planned for April. The projects' impacts are summarized below.

- **CVE –** The initial emergence of the virus in China delayed shipments of in-vehicle OBUs, which caused a delay in installations. As the virus moved into the U.S., the project team had to slow the pace of integration and testing due to the travel restrictions that prevented the team from working together in Columbus. The activities continued remotely, albeit at a slower pace.
- **EPM –** The vendor for the solution, ParkMobile, had an immediate impact on their business – with the overnight downturn in parking, their financial position precluded them from continuing to use contract development resources for the ParkColumbus application. Work continued, but again at a slower pace.
- **PTA and MAPCD –** The main impact was the shift in the project teams interaction with participants, moving from in-person to virtual engagements. The MAPCD demonstration also ended a few weeks early (in March as opposed to April) although exit interviews were conducted virtually until they were completed in fall 2020.

- **CEAV –** A sudden stop of the shuttle on February 20, 2020, resulted in a passenger slipping from her seat to the floor of the shuttle. This paused passenger service from February to May while the incident was investigated, and mitigations identified, approved by NHTSA and implemented. Unfortunately, by the time these mitigations were approved in May, stay-at-home orders and social distancing guidelines made passenger service impossible to resume. The project team quickly engaged with stakeholders to identify alternate use cases that were in alignment with the project needs and goals, settling on the use of the shuttle for food pantry delivery to the community from St. Stephen's Community House. The food pantry service was approved by USDOT in May as an authorized, temporary, non-program use of the shuttle. The service launched in July 2020.

For one project in particular, MMTPA/CPS, the COVID-19 pandemic exacerbated risks and challenges that the team was already working actively to mitigate. This specifically included finalizing agreements with mobility providers for participation in CPS, and finalizing the terms of ownership with COTA, the designated end-owner for the solution. Development and launch, originally planned for March 2020, had already been delayed to May due to these legal and business decision challenges from mobility providers. However, these negotiations stalled completely with the pandemic. In addition, like most other transit agencies in the pandemic, COTA ridership dropped dramatically. Through the course of working with the City on the MMTPA/CPS project, the challenges and limitations of COTA's fare collection system were at the forefront of conversations. These challenges, like many other risks, were amplified by the pandemic and the increasing emphasis on enabling widespread adoption/use of contactless payment. Therefore, COTA changed its focus to enhancing its fare collection system and stepped away from ownership of the MMTPA/CPS project. In July 2020, the City recommended the CPS project be discontinued and MMTPA continue. After coordination with USDOT, this request was accepted in August 2020 and a subsequent award reduction was negotiated.

2.2.5. Year 5: Data Collection and Evaluation

The final year of the demonstration began with the launch of the CVE and EPM projects. The CVE project completed recruiting, successfully enrolling 311 private participants in addition to the many City and COTA fleet vehicles that were also equipped. The project went live in October 2020 after extensive testing and integration activities that began in spring 2020. EPM also launched, with the City-developed predictive availability model included as one of the key enhancements the project made to the ParkColumbus application. The final project, MMTPA (branded as Pivot) also launched in December, a significant milestone after risks including finalizing mobility provider agreements and loss of COTA as the end-product owner impacted the schedule and scope for the project.

The final months of the Smart Columbus Program focused on working with OSU and the performance measurement teams to evaluate the impact of the projects on the city, while the project teams completed demonstrations, data collection and final updates to all documentation. Nearly all projects included some type of survey effort to gather feedback from the most important user groups, the residents of Columbus. The performance measurement team combined this qualitative feedback with quantitative data generated by the projects and housed on the SCOS to evaluate the projects' results compared with goals. **Chapter 4** includes a summary of these results.

Finally, the PMO also focused efforts around sustaining many of the projects in the portfolio, including the CVE, EPM, SCOS, MMTPA and SMH projects. These projects will continue post-demonstration as City-administered efforts. Some projects, such as the SCOS and MMTPA, are anticipated to expand and evolve to solve challenges within the city. These projects will continue to be operated and maintained but may also continue with the development and implementation of enhancements. Others, such as EPM (ParkColumbus), CVE and SMH will continue to be production systems (operated and maintained by the City as the owner) from which residents will benefit. Later chapters in this document discuss specific efforts around the sustainability of each project.

2.3. PROGRAM SCOPE

The previous section provided the highlights of each year of the SCC demonstration. There were many challenges, expected and unexpected, and the mitigations varied from major to minor to accommodate these issues as they were encountered. USDOT was an active partner in this process, and all major mitigations were reviewed during the City's regular exchanges with them and ultimately documented in amendments to the Cooperative Agreement. A summary of these changes and the timeline of when they occurred is presented in **Table 2-2**. In many ways, they also tell the story of how the program evolved over time, with roles and requirements changing and projects being removed.

Table 2: List of Smart Columbus Program Amendments

Amendment	Date	Changes
Amendment 1	March 16, 2017	Ÿ Change the accounting code for the funding previously obligated on the base award
Amendment 2	August 7, 2018	Ÿ Obligate funding that was previously designated as "subject to availability"
Amendment 3	September 18, 2018	Ÿ Extend the previous period of performance by nine months Ÿ Update the Approved Agreement Budget Ÿ Revise the Key Personnel clause Ÿ Revise/clarify various award terms
Amendment 4	May 27, 2019	Ÿ Decrease the value of the agreement by $3,137,325 (which consists of a decrease in federal share of $2,127,000 plus a decrease in nonfederal share of $1,010,325) Ÿ Delete the Truck Platooning project from the agreement Ÿ Revise the Key Personnel clause Ÿ Revise/clarify various award terms
Amendment 5	July 8, 2019	Ÿ Obligate funding that was previously designated as "subject to availability"
Amendment 6	August 27, 2019	Ÿ Update the Approved Agreement Budget
Amendment 7	September 17, 2020	Ÿ Reduce the value of the agreement by $1,267,047 (which consists of a decrease in federal share of $861,592 plus a decrease in nonfederal share of $405,455) Ÿ Delete the CPS project from the remainder of the agreement Ÿ Update the Approved Agreement Budget Ÿ Delete a Task E deliverable Ÿ Update the Leveraged Partner Resources clause Ÿ Make administrative updates to the award text

Source: USDOT and the City of Columbus

2.3.1. Paul G. Allen Family Foundation Grant Acknowledgment and Summary

The City received the USDOT SCC award in 2016 in parallel with a $10 million grant award from the Paul G. Allen Family Foundation. The PMO managed the Paul G. Allen Family Foundation and USDOT programs, which both kicked off in August 2016.

The vision of the USDOT SCC was to demonstrate and evaluate a holistic, integrated approach to improving surface transportation performance within a city and integrating this approach with other smart city domains such as public safety, public services and energy. USDOT intended for this challenge to address how emerging transportation data, technologies, and applications can be integrated with existing systems in a city to address transportation challenges.

The Paul G. Allen Family Foundation's grant and priorities were intended to reduce greenhouse gas emissions through the electrification and decarbonization of the transportation sector. Collectively, these priorities were known as the Electrification Program.

The five Electrification Program priorities were:

1. Decarbonization
2. Fleet Electric Vehicle Adoption
3. Transit, Autonomous, and Multimodal Systems
4. Consumer Electric Vehicle Adoption
5. Charging Infrastructure

With the PMO managing both programs, alignment and awareness were important between the two programs. As such, the SCC and the Electrification Program had the following three primary intersection points:

- **CEAV and MMTPA –** Electrification Program Priority 3
- **SMH –** Electrification Program Priority 5
- **SCOS –** Electrification Program Priorities 2-5

Consolidation of program management between these two efforts ensured coordination and alignment, which avoided duplication. The Electrification Program concluded in March 2020, with results published at the end of July. The Electrification Program published both a final report[18] and a digital playbook for city officials, policy makers, business leaders and influencers.[19]

2.4. ACHIEVEMENT OF USDOT SMART CITY VISION

USDOT's SCC notice specifically asked applicants how they would use emerging transportation technologies to address their most pressing problems such as traffic congestion, crashes, infant mortality, poverty and unemployment; challenges not uncommon to metropolitan areas. As the winner of USDOT's SCC, Columbus proposed a comprehensive, integrated plan addressing challenges in residential, commercial, freight, and downtown districts. Using new technologies, including CVs and infrastructure, an integrated data platform, automated vehicles (AVs), and smartphone applications designed to enhance human services, Columbus aimed to solve problems and address the needs of residents, businesses, and stakeholders. The City's vision and investment in advanced and innovative technologies sought to enhance safety and mobility, and create opportunities for residents to better access jobs, fresh food, services, education, health care and recreation.

Aligning Columbus' goals with USDOT's Vision Elements required a holistic approach to addressing transportation challenges faced in the City. Each project addressed multiple USDOT Vision Elements, as described in each project chapter. The projects were grouped into three overarching themes: Enabling

[18] https://d2rfd3nxvhnf29.cloudfront.net/2021-03/SCC-PGAFF-FinalReport_07.31.20.pdf

[19] http://smart.columbus.gov/playbook

Technologies, Enhanced Human Services and Emerging Technologies (see **Figure 1-1** in **Chapter 1**). Organizing the projects by themes illustrates the connections between diverse projects, demonstrating the integrated and holistic approach needed to deliver the Smart Columbus Program to users. In addition to the projects falling under these themes, the SCOS serves as the integral backbone of current and future smart city projects. The SCOS was a major achievement of the program. While the concept of a data environment to ingest and disseminate both public and private data is not new, the architecture and platform for the SCOS uses best-of-breed technologies including open-source and commercial off-the-shelf tools to enable better decision-making and problem-solving for all users.

In evaluating the qualitative and quantitative results, the Smart Columbus Program addressed City challenges and met several of the original expectations defined in the City's smart city vision. The project addressed transportation challenges by deploying applications and strategies in the following USDOT Vision Elements:

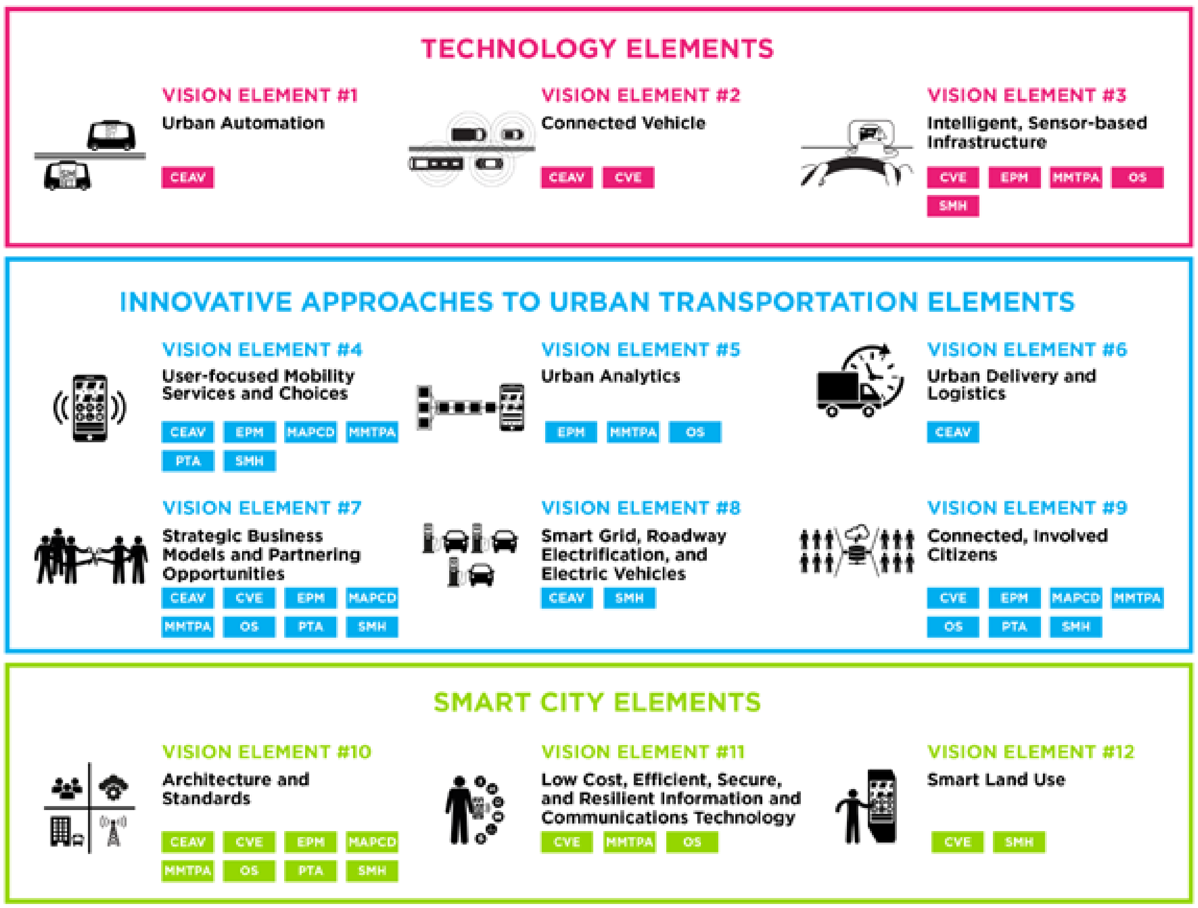

Figure 2-7: Alignment of Smart Columbus Program to USDOT Smart City Vision Elements

Source: USDOT and City of Columbus

The direct outcomes related to USDOT's 12 smart city Vision Elements are outlined below:

- **Urban Automation –** USDOT recognizes that automated transportation offers tremendous possibilities for enhancing safety, mobility, accessibility, equity, and the environment. Through the CEAV project, the Smart Columbus Program demonstrated and assessed the use of automated transportation applications and systems for the movement of goods and people through the three deployments. Collectively, these deployments provided a unique set of use cases:
  - The Smart Circuit deployment first demonstrated automated vehicle operation in an urbanized area, documenting the challenges with integrating an AV into mixed-use traffic.
  - The Linden LEAP passenger service specifically sought to apply an AV as the solution for first mile/last mile (FMLM) access to public transportation, and identified many lessons learned that must be addressed to fully leverage this technology in long-term use cases similar to the Linden LEAP.
  - The Linden LEAP food pantry service, although unexpected, also solved a specific use case in the community during the pandemic while demonstrating the use of an AV for the movement of goods. While not a long-term solution, it also leveraged the solution and route developed for the Linden LEAP passenger service project. This ensured that the project continued to contribute to the Smart Columbus Program goals even if not able to carry passengers, while also collecting important performance-related data on the AV.
- **Connected Vehicles (CVs) –**This Vision Element refers to the use of vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communications to provide connectivity that will enable safety, mobility, and environmental applications. At the time of the SCC, USDOT advocated for expanded demonstrations of these applications using Dedicated Short Range Communications (DSRC). Columbus not only successfully implemented their CVE pilot using DSRC but did so during a time of transition for the spectrum, using a two-channel approach to successfully demonstrate both V2V and V2I safety and mobility applications. Similarly, two of the CVE applications (transit vehicle interaction event recording or TVIER, and vehicle data for transportation operations or VDTO) demonstrated that the data derived from CVs provided useful insights to transportation operators both at the City and COTA, helping to understand demand and assist in predicting and responding to movements around a city. The CEAVs in the Linden LEAP deployment were also equipped with onboard units enabling them to broadcast basic safety messages and engage in V2V interactions with other equipped vehicles.
- **Intelligent, Sensor-Based Infrastructure –** This Vision Element reflects use of intelligent infrastructure to collect and report real-time data, and the integration of this data into existing transportation data and operations. Collectively, the integrated data is used to monitor transportation assets to improve infrastructure management, reduce maintenance costs, prioritize investment decisions, and ensure a state of good repair.
  - The SMH project deployed IKs that integrated the MMTPA (Pivot) with data from existing and new bike-share docks that report the number of available bikes. Because Pivot also indicates availability of scooters, the use of this application, both at SMH and around the city, help travelers understand the location of available transportation options.
  - The SCOS also collaborated with the City's Division of Infrastructure Management to create an Employee and Work Order Allocation dashboard to assist in improving agency efficiency. It is estimated that this dashboard will save the division up to 30 man-hours per week.
  - The CVE project includes several V2I applications, including red light violation warning (7,637 alerts generated and provided to participating vehicles), reduced speed in school zones (1,349 alerts generated and provided to participating vehicles), and signal priority and preemption for transit, freight and emergency vehicles (equipped intersections indicated an improvement in approach times).

- Finally, the EPM project used data from in-pavement sensors as one source of data for its predictive availability model, in combination with transaction data from the City and ParkMobile (the EPM vendor).

- **Urban Analytics –** This Vision Element includes platforms for understanding and analyzing data to address complex urban challenges and measuring the performance of a transportation network.
  - The EPM and SCOS projects worked together, supplementing project-generated data with data from the City's Parking Services Division to develop and implement the parking prediction model, which applied analytics and machine learning to three different parking-related datasets to predict future conditions related to on-street parking availability. The outcomes of this model were also integrated with the EPM application. The result is a direct demonstration of how analytics can be applied across sectors to create new and different applications.
  - With the support and contribution of OSU, the program was able to successfully quantify transportation-related performance measures on 22 of 29 outcomes to understand the impact of all proposed solutions, both individually and collectively, on the six outcomes sought by the City in its application and PfMP. The results calculated by OSU and documented in the performance measures results indicate greater access to jobs and services and increases in transit, walking or cycling.
  - The Pivot app deployed through the MMTPA project uses machine learning and both external data sources (from ODOT and INRIX) and the traveler's own trip history to recommend trip plans.

- **User-Focused Mobility Services and Choices –** This Vision Element consists of strategies, initiatives, and services that increase transportation choices and options by supporting and improving mobility for all travelers, including aging Americans and persons with disabilities. Open data and technology enable the efficient coordination, use, and management of all mobility services in the system. Most projects have some link to this element: the SMH project provided ten different mobility enhancements across six sites to give travelers options, the CEAV project provided various connections around the city (Smart Circuit provided connection from across the Scioto River to downtown while the Linden LEAP provided connection between two SMHs and community locations), EPM delivered a website and mobile app for both drivers and parking operators, and PTA provided an app, website, and call center to allow for on-demand non-emergency medical transportation services. Two projects had this element as part of their primary vision:
  - The **MMTPA** project (Pivot) provides a comprehensive planning tool that can help travelers get to their destination using multiple modes of transportation. The Pivot app offers real-time mobility options for users in the Columbus region and includes public transit, ride-hail, bike-share, scooter-share, and ride-share options. Pivot includes many features, including customizing user preferences, nearby ride options for bus, scooter, and bike, and live transit alerts through the app. The Pivot routing engine uses machine learning to make recommendations based on traveler behavior and preferences, and to provide trip optimization based on historical and real-time data such as INRIX and COTA.
  - The **MAPCD** project used the Wayfinder App, a customized, highly detailed, turn-by-turn navigation app specially built for people with cognitive disabilities. WayFinder enables people with cognitive disabilities to travel with greater independence and autonomy, and transition from paratransit services to fixed-route bus systems. Phone-based GPS tracking allows WayFinder to safely guide users with step-by-step visual and audio instructions. The app also allows their caregiver to develop instructions based on the unique needs of their loved one. This solution gets participants from Point A to Point B safely using the bus, making it easier to independently make important trips like going to the grocery store or getting to work.

- **Urban Delivery and Logistics –** This Vision Element seeks to demonstrate innovative technology solutions for urban goods movement; in the case of the CEAV project, the COVID-19 pandemic forced the project theme to rethink the use case for the Linden LEAP, but another user need quickly emerged, which was to increase food delivery into the communities that needed it most. With the shuttles sidelined due to social distancing guidelines, the vehicles were able to be used as urban delivery vehicles extending the reach and distribution of the food pantry at St. Stephen's Community House.
- **Strategic Business Models and Partnering Opportunities –** This Vision Element encourages opportunities to leverage creative strategic partnerships that draw in stakeholders – including private sector, nonprofit, foundation/philanthropic, academia/University Transportation Center, and other public agencies – to advance smart city solutions. It recognizes that successful implementation of a smart city relies on strategic partnering opportunities between public agencies and the private sector. In the case of the Smart Columbus Program, while there were many opportunities initially, it took time and effort to evaluate each one to carefully curate the partnerships that made the most sense in terms of advancing the City and USDOT's vision. The following key partnerships were key to the successful delivery of the Smart Columbus Program:
    - **ODOT/DriveOhio –** Development resources for SCOS, position correction and SCMS for CVE and CEAV, funding and management of the first CEAV deployment, and coordination on CVE interoperability.
    - **COTA –** Support for SMH (coordination with BRT and transit stations), CEAV (training, response, standard operating procedures), MAPCD (coordination and resources for participant training), and CVE (vehicle installations and application development).
    - **St. Stephen's Community House –** Coordination of SMH project site, CEAV Linden LEAP station and origin of food pantry service.
    - **OSU –** Principal investigator for several projects, including PTA, MAPCD, CEAV, MMTPA, and SMH. Providing funding and planning support for the CEAV project. Performed evaluations for program outcomes, including mobility, customer satisfaction, and economic impact. In addition, OSU was responsible for providing research support for and guiding the development of the Smart Columbus Data Management Plan[20] and Data Privacy Plan[21] and participating on the Privacy and Security Board.
    - **Amazon –** Provided SCOS hosting and tools.
    - **Battelle –** Provided data curation for SCOS.
    - **Sidewalk Labs –** Performed research and stakeholder interviews regarding NEMT challenges faced by pregnant individuals. This information introduced innovative platforms to solve existing issues and meet the needs of pregnant individuals. The Sidewalk Labs report laid the foundation for the development of the PTA project.
    - **AT&T –** Provided telecommunications support for the Experience Center.
    - **The Columbus Partnership –** Provided support for Experience Center development and operations as well as a partner on the first CEAV deployment.
    - Specific projects also demonstrate the achievement of this Vision Element:

[20] *https://www.smartcolumbusos.com/images/2020/PDF/SCC-E-DataManagementPlan-Update-v1.pdf*

[21] *https://d3hzplpmmz6qe4.cloudfront.net/2019-07/Smart%20Columbus%20Operating%20System%20Data%20Privacy%20Plan_0.pdf*

  - **SMH –** Leveraged Experience Columbus partnership to procure IKs from IKE Smart City, as well as coordinating with all six site stakeholders on the design and installation of the infrastructure.
  - **PTA –** While the City's partnership with Sidewalk Labs research created the project, it was the engagement and collaboration with the managed care organizations (MCOs) to develop and deliver the solution that was critical to successful recruitment and demonstration. For this project, there were many groups interested in improving birth outcome and mitigating social determinants.
  - **CVE –** Partnerships with COTA and Franklin County contributed directly to achieving both RSU and OBU installations. In addition, the work of the Communications Team to engage with local business (2 Brothers Automotive) helped to meet workforce development goals even during the pandemic.
  - **EPM –** The PMO's partnership with the Division of Parking Services enabled the project to leverage an existing mobile payment contract with Conduent/ParkMobile to integrate EPM requirements into the ParkColumbus solution; Experience Columbus also played a key role in engaging with parking operators on the project.

- **Smart Grid, Roadway Electrification and EVs**
  - The Paul G. Allen Family Foundation grant had the singular goal of measurably decreasing greenhouse gas emissions created by light-duty transportation in the Columbus region. **Table 2-3** outlines the Paul G. Allen Family Foundation grant's five Electrification Program priorities and high-level results.

Table 3: Summary of Paul G. Allen Family Foundation Program Results

Paul G. Allen Family Foundation Grant Priority	% of Goal Complete
Decarbonization:	
Utility Scaled Renewables	2%
Grid Modernization/Efficiency	138%
Fleet EV Adoption:	
Public Fleet EVs	96%
Private Fleet EVs	8%
Transportation Service Provider EVs	55%
Transit, Autonomous, and Multimodal Systems in the City:	
CEAV	100%
Electric Bikes	72%
Bike Lane Infrastructure	132%
Consumer EV Adoption:	
EV Market Penetration	130%
Estimated Equivalent # of EVs purchased	115%
Accelerator Partner Program	100%

Paul G. Allen Family Foundation Grant Priority	% of Goal Complete
Charging Infrastructure:	
Residential Charging	59%
Public Access Charging	78%
Workplace Charging	161%
Fleet Charging	86%
Building & Zoning Changes to Support EV Charging	233%

Source: Paul G. Allen Family Foundation Final Report[22]

- Relevant to the USDOT Cooperative Agreement projects, the SMH project deployed EV charging stations at the Northern Lights Park and Ride facility, while the first CEAV deployment with May Mobility created additional EV charging infrastructure in the city.

- **Connected, Involved Citizens –** This Vision Element consists of strategies, local campaigns and processes to proactively engage and inform citizens at the individual level to increase personal mobility.
  - The success of demonstrating each project was inherently dependent on achieving this vision. Each project chapter in this document discusses the respective, specific strategies and campaigns for each project. Although the projects' goals and objectives varied, the consistent theme of improved mobility was present in all campaigns. Each project demonstrated the deployment of hardware (CVE and SMH), software (MMTPA, EPM, MAPCD, PTA) and open data platforms (the SCOS and MMTPA). CVE, for example, recruited over 300 private participants to install OBUs and heads-up displays in their private vehicles.
  - The Smart Columbus Program also demonstrates the ability for residents to leverage broad access to open government data through the SCOS, which enables all users to serve as co-creators and co-producers of new and innovative transportation services. Some good examples of this is the work of volunteers (including business analysts and project managers of the Smart Columbus Open Data Enthusiasts (SCODE) meetup group) to build and test a mobile solution in partnership with the Reeb Avenue Center using data on the SCOS. The application provides easy-to-use filters to select the type of services they are looking for – including food, shelter and transportation support.[23] The SCOS also hosted two Hackathons to generate user stories and sample products using data hosted on the SCOS. Users can see these stories and be inspired by stories of data from the SCOS being put into action through the "Case Studies" tab on the SCOS website.[24] The SCOS project team has also shared their work with the open-source community for future use and advancement – the parking prediction model is open source and available on GitHub for others to use.

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22 https://d2rfd3nxvhnf29.cloudfront.net/2021-03/SCC-PGAFF-FinalReport_07.31.20.pdf

23 https://www.smartcolumbusos.com/data-stories/volunteer-coders-help-families-in-need-find-food-pantries

24 https://www.smartcolumbusos.com/data-stories/case-studies

  - Both the USDOT and the Paul G. Allen Family Foundation Electrification Program efforts relied on working groups throughout the agreement timeframes. All working groups relied on volunteer participation and evolved as necessary to maintain this engagement throughout the program. The working groups helped to flesh out user needs and improve adoption, as well as drafting and reviewing policies related to data management, data privacy, and sustainability.
- **Architecture and Standards –** This Vision Element emphasizes architectures – governed by rules, documentation, and standards – that may be extended to a nationwide or broader deployment. All projects abide by the current architecture and standards of the industry.
  - The Smart Columbus Program, in developing the System Architecture and Standards Plan (SASP), applied the National ITS reference architecture, known as Architecture Reference for Cooperative and Intelligent Transportation (ARC-IT) (and the associated systems engineering tool for information technology (SET-IT) software tool), and published ITS standards to advance the documentation of interoperable ITS capabilities which are nationally extensible.
  - Perhaps more critically, the process of using SET-IT in the development of the program architecture identified many areas where customization was required to accurately and thoroughly describe the various systems and projects being designed. After the first draft of the SASP was published in early 2019, USDOT updated SET-IT twice (Version 8.3 in August 2019 and Version 9.0 in November 2020); coincidentally, the updates to the tool reflected the City's experience in applying it. The Version 8.3 update included more flexibility in generating architectures, and thereby required significantly less customization in the diagrams. Version 9.0 also added more service packages to describe the type of technologies being deployed and expanded the Communications view. Because of the alignment of Smart Columbus project updates with these version updates to SET-IT, the City updated their architecture each time to remain current and consistent with these nationally recommended tools.
- **Low cost, efficient, secure and resilient –** This Vision Element includes strategies and practices that advance information and communications technology (ICT) that is affordable, adaptable, efficient, secure and resilient, including integrated telecommunications platforms, enterprise software, storage, and visualization systems.
  - The SCOS is perhaps the best example from the Smart Columbus Program demonstrating this vision. The final product is a replicable, extensible, sustainable data management platform serving the needs of public agencies, researchers and entrepreneurs. It created the necessary software, storage and visualization systems to enable both the projects and other City departments (such as the Division of Infrastructure Management) to access, store and manipulate information.
  - The SCOS and the program overall, also demonstrate the criticality and priority of privacy and security. As discussed in **Chapter 3**, the protection of Personally Identifiable Information (PII) was identified as an early priority in the program, and from that point forward, governed the development of data management and privacy plan development and implementation. The SCOS does not collect or store any PII, and for the Smart Columbus Program overall, the collection of PII was limited to performance measurement activities such as surveys, and collected and protected it only for these purposes.
  - MMTPA (Pivot) uses a foundation of open, free, and proven technologies. There are no dependencies on subscription services, proprietary code, or commercially licensed data. The platform is made of containerized microservices, allowing for interoperability with the SCOS or future host environment. The custom code can be entirely redistributed as MIT-licensed, open-source software, if desired. The platform includes a distributed ledger ("blockchain") that offers redundancy, transparency, shared governance, and long-term viability for Columbus and other cities that decide to deploy the platform.

  - CVE implemented rigorous network security design practices when architecting the physical and logical elements of the system. This approach isolates CVE from other critical systems while providing for both the immediate and long-term capacity needs. Advanced IPv6 capable, layer 3 network switches, deployed in multiple strategic locations, and paired with field-hardened local switches, all operating on a redundant network, ensure an efficient, secure and resilient communications backbone.

- **Smart Land Use –** This Vision Element includes strategies and practices that ensure land use is optimized through a combination of planning and innovation deployments, altogether designed to contribute to a better-connected community that expands its range of transportation choices and access to employment, housing, education and health services. As with the vision for connected and involved citizens, the focus on smart land use was inherent in the City's original application and was executed through the infrastructure-focused deployments in SMH and CVE. Both projects leveraged COTA's existing bus rapid transit (BRT) corridor.

  - SMH worked to consolidate mode options near and along this corridor, improving FMLM connections to the BRT stations and community resources located on/near the corridor. SMH promote transit-oriented travel by improving access to modes that directly improve FMLM trips including scooters and bikes. SMHs have been developed around community places of interest to provide access to resources (transit stops, libraries, community centers) by aggregating transportation resources and services that will provide improved mobility for those in the areas around the SMH facilities.

  - CVE also leveraged existing City investment in infrastructure by aligning with the Columbus Traffic Signal System (CTSS) project, while also coordinating with the COTA BRT line (Cleveland Avenue) and key corridors relative to passenger routes (High Street), commercial activity (Morse Road) and freight (Alum Creek). The CVE project also coordinated closely with DriveOhio to ensure interoperability and consistency with long-range, regional considerations in terms of sustainability, ensuring that the infrastructure that was deployed can easily tie in to other CV deployments in the state and region, both in terms of the geographic location of the corridors as well as the technology and architecture that was used. This ensures a sustainable path forward for this technology.

Over the course of the four-plus years of the Cooperative Agreement, the Smart Columbus Program encountered many challenges, both anticipated and unanticipated. This chapter provides a summary of activity by year and how the risks and challenges impacted what the City originally set out to do. While the path to delivering on USDOT's 12 Vision Elements for a smart city took various detours, the PMO ultimately was able to deliver on all 12 elements through consistent engagement with residents through various channels (as the project chapters highlight). The specific achievement and example of how each project, or the program as a whole, satisfied these elements was not always what was originally anticipated, but demonstrates the importance of keeping this vision at the forefront of the planning and deployment efforts.

Chapter 3. Program Management and Delivery Summary

The Cooperative Agreement between the City of Columbus and the U.S. Department of Transportation (USDOT) provided the general structure for delivering the Smart City Challenge (SCC) documentation and ensuring the program could demonstrate, quantify and evaluate project impacts. In alignment with the statement of work and tasks provided in the Cooperative Agreement, the following sections discuss the City's approach to delivering the program:

- Program Management
- Communications
- Data Management, Security and Privacy
- Safety Management and Human Use
- Program Management Lessons Learned
- Program Financials

The program financials section covers funding sources and program costs. Funding is broken out by project and by funding partner. Program costs are summarized by project, detailing deployment (implementation) versus operational (ongoing) costs. This section concludes with key takeaways specific to the financial elements of program management.

3.1. PROGRAM MANAGEMENT

The USDOT SCC program was the first of its kind, and both USDOT and the City brought numerous resources to the table. The City approached the delivery of the SCC by establishing a Program Management Office (PMO) consisting of City of Columbus employees. Under the leadership of the Chief Innovation Officer for the City of Columbus, the PMO was responsible for the delivery and execution of the USDOT SCC program, named Smart Columbus.

The delivery of the USDOT Cooperative Agreement had two layers of organization, first with the PMO responsible for program delivery and second with an informal public-private partnership (P3) between the City of Columbus and The Columbus Partnership, a nonprofit organization made up of CEOs from Columbus' leading businesses and institutions. Private donations to The Columbus Partnership to support Columbus' smart city journey were used in part to amplify the visibility of the Smart Columbus Program within the region, state and nation. Communications responsibilities were centralized and shared, with the City leading project- and program-related communications, and The Columbus Partnership leading national media, trade media and industry event strategies in consultation with the City's Communications Project Manager. The PMO had primary responsibility for delivering the program and all projects and activities funded by USDOT as defined in the Cooperative Agreement.

The program was delivered using a PMO approach supported by principles from the Project Management Body of Knowledge (PMBOK). The team was structured around program and project deliverables. Program deliverables focused on overarching activities related to program management and finance, data management and privacy, performance measurement, communications, and safety management, with the PMO coordinating as needed with the project teams. Project-level deliverables focused on systems engineering, testing and integration, and operations and maintenance.

The size and structure of the PMO evolved with the program. Immediately following award, the PMO was a relatively lean organization, with leadership and staff still responsible for other projects and efforts in the City. In early 2017, the City announced the hiring of its first-ever Chief Innovation Officer. The PMO was moved to be under his leadership, relocated to the Idea Foundry, co-located with The Columbus Partnership and restructured to include additional dedicated staff. The PMO was restructured in mid-2017, bringing in a program manager and a deputy program manager, both completely dedicated to project development and delivery. In addition, the initial Project Management Plan (PMP) was revised, reflecting the more robust responsibility assignment matrix and project management processes. These changes were made to ensure that all aspects of program delivery and evaluation were assigned within the PMO.

Consultant support from multiple firms including HNTB, Michael Baker International (MBI), Battelle, Accenture, Engage and many others was also procured competitively throughout the Cooperative Agreement timeframe to provide leadership and task support in the areas of program management, project development and communications in alignment with the Cooperative Agreement tasks. The PMO ensured that there were subject matter experts (SMEs) and supporting resources, whether City or consultant staff, in all of the key areas specified in the Cooperative Agreement (systems engineering, performance measurement and evaluation, data management and privacy, safety management, and communications). The final PMO structure as of January 2021 is shown in **Figure 3-1**. All consultants are also summarized in **Table 3-1** and **Table 3-2** following the organizational chart; some notable examples include:

- The HNTB team (including WSP and other subconsultants) provided a dedicated program manager and technical lead for each project while helping to deliver most deliverables in the Cooperative Agreement
- Michael Baker (including Battelle and Taivara) provided staff augmentation to the PMO, through the assignment of a dedicated project manager for the Connected Electric Autonomous Vehicles (CEAV) and Smart Mobility Hubs (SMH) projects, technical support for the Multimodal Trip Planning Application (MMTPA) and Smart Columbus Operating System (SCOS) projects, and an executive assistant to assist with management, reporting and invoicing
- Accenture led the development and operations of the SCOS, with Battelle providing data curation and development assistance to both the SCOS and the program

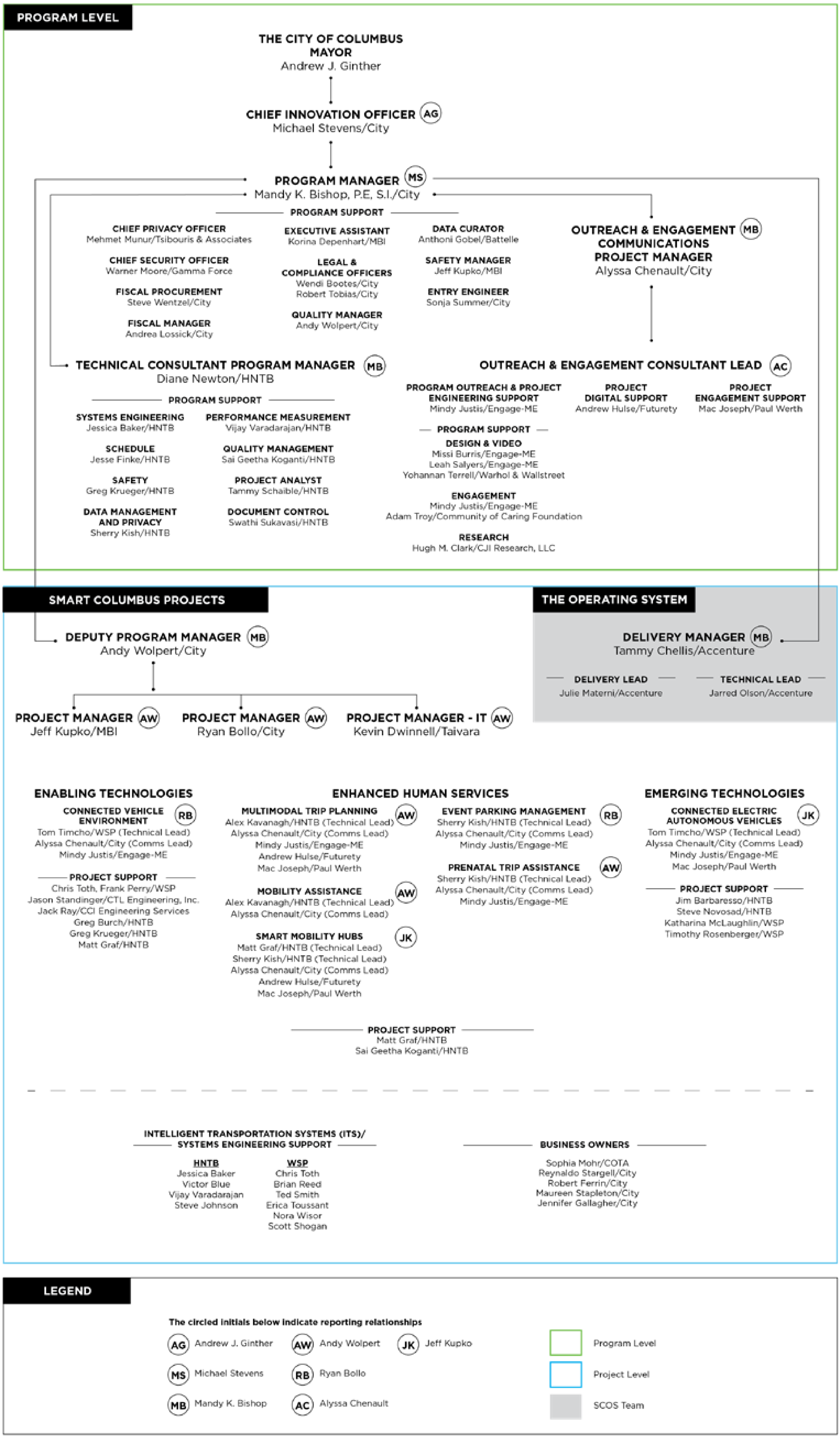


Figure 3-1: Smart Columbus Program Management Office Structure – January 2021

Source: City of Columbus

The organization chart includes consultant staff that supported the program management and project delivery for both the technical and communications perspectives. **Table 3-1** summarizes the procured consultant support on the technical side of the program, while the next section provides more insight into the Communications staff.

Table 4: Program Consultants, Competencies and Projects

Name	Competencies	Project/Program Item
Accenture, formerly Pillar Technology (Gamma Force, Unicon)	Agile development, information technology project management, data management and privacy (including chief security officer role)	Ÿ SCOS Ÿ Program
Proteon	Agile development, information technology project management; software architect (August 2017 to December 2019)	Ÿ SCOS
ALE	Systems Engineering (November 2017 to December 2018)	Ÿ All projects Ÿ Program (Systems Engineering Management Plan)
Battelle (cost-share and subcontractor to MBI)	Development, Data Curation, Safety Management	Ÿ SCOS Ÿ Program (Safety Management, Performance Measurement)
HNTB (WSP, Smart Services, Inc. (SSI), CCI, CTL, Tsibouris and Associates, Advarra)	Program management, project management and systems engineering, safety management and institutional review board (IRB), performance measurement, data management and privacy (including chief privacy officer role), human use, project development and testing (including surveying, plan development,) and final report	Ÿ Support of all projects (SCOS, MAPCD, PTA, CVE, EPM, CEAV, MMPTA, SMH) Ÿ Development of program deliverables
Michael Baker International, MBI (Taivara)	Project management, safety management, project development and testing, information technology subject matter expertise (project-level)	Ÿ Project manager for SMH, CEAV Ÿ Support for MMPTA, PTA, MAPCD, EPM, CVE and SCOS Ÿ Safety manager Ÿ Development of program deliverables

Source: City of Columbus

3.2. COMMUNICATIONS

Winning the SCC was a significant accomplishment for the City of Columbus and the region. The communications team became responsible for raising awareness as well as managing the public's expectations for the program. The Columbus Partnership invested private resources early to promote the win in the media locally and nationally, and establish the Smart Columbus brand, including logo, visual identity and messaging. This early investment grew the profile of the program within the community, which set the groundwork for the City of Columbus to begin gathering information on specific user needs that could be addressed by the new technologies. The City of Columbus contracted with a professional services agency, Engage (MurphyEpson), to assist with the end-user engagement and recruitment. A year before the first project was set to launch, the City hired a full-time Communications Project Manager to lead communications, outreach and recruitment for each project.

As end-user needs were obtained and informed the Concept of Operations (ConOps) documents in the systems engineering process[25], the communication approach shifted from program-level to project-level. Each project's messaging, from fact sheets and end-user surveys to recruitment materials, was developed individually, based on the project's unique audience, stakeholders and engagement needs. Information about the entire program as well as each individual project was available on the project website. This helped the public and project-specific audiences understand how everything fit together. However, the faster deployment timeline and broad awareness campaign of the Paul G. Allen Family Foundation grant programs, as well as the fact that the programs had demographically and geographically different target audiences, caused some confusion. The City redoubled its efforts to ensure the details of the USDOT projects and possible outcomes were made very clear. As specified in Task G of the SCC Cooperative Agreement, the following were produced:

- Communications and outreach plan
- Materials developed to support communication and outreach goals
- Promotional video
- Website
- Workshops/conferences/trade shows (as approved)
- Webinars

A promotional video[26] was developed in May 2016. An initial website was created to support the program and launched in 2017. The website (columbus.gov/smartcolumbus) was revamped to improve the user experience and relaunched at smart.columbus.gov in June 2018 (see **Figure 3-2**). Project-specific communication and outreach plans were developed in October 2018. Materials were developed as needed to support each project (see **Appendix D**). The City of Columbus produced over 30 webinars to share information about the systems engineering process and lessons learned so peer cities could gain insight as the projects launched.

[25] *The systems engineering process is described in Section 2.1 of Chapter 2*

[26] *https://youtu.be/Cl4nWJoZmwI*

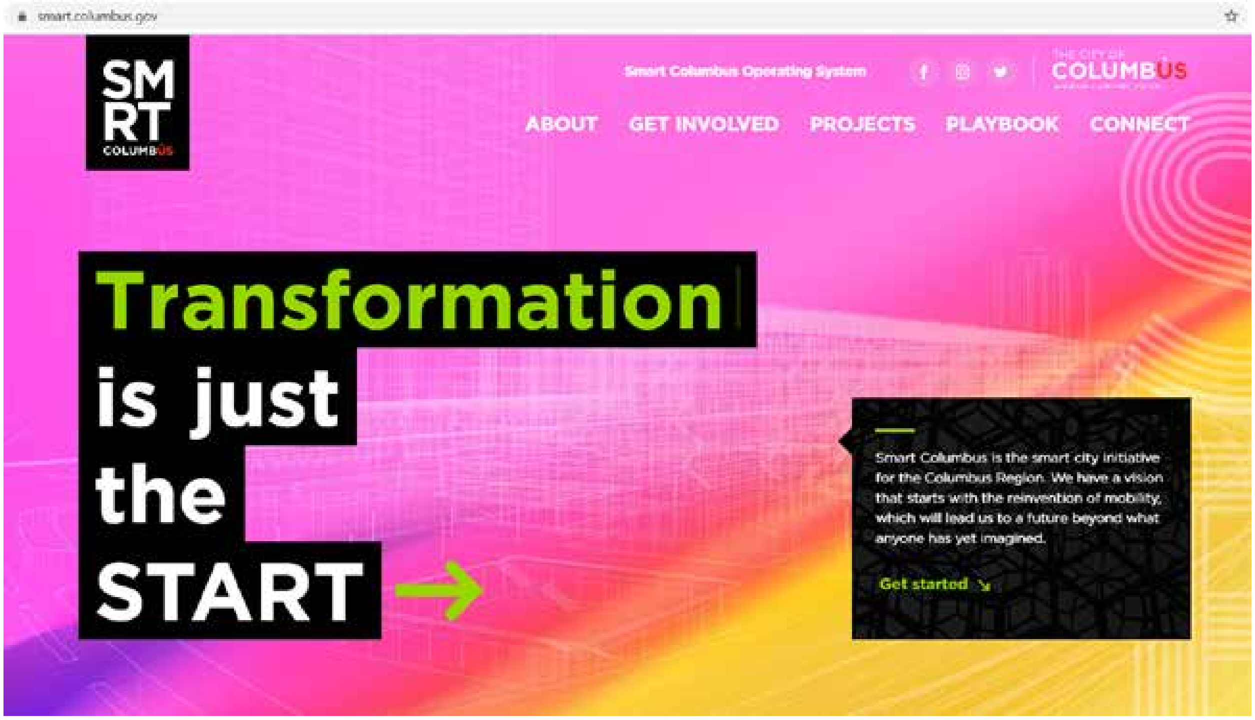


Figure 3-2: Smart Columbus Website

Source: City of Columbus

3.2.1. Competencies and Tools

A team with diverse skills and competencies supported the communication and outreach plan activities.

Table 5: Communications Partners, Projects and Skillsets

Name	Competencies	Projects
Communications Project Manager	Communications, Strategy/Planning, Stakeholder Engagement, Grassroots Engagement, Messaging, Copywriting, Public Relations, Public Speaking, Project Management, Vendor Management	Strategic integration of all projects (SCOS, MAPCD, PTA, CVE, EPM, CEAV, MMTPA, SMH)
Engage	Strategy/Planning, Graphic Design, Messaging, Copywriting, End User and Grassroots Engagement, Video Capture and Editing, Research Design and Analysis	Support of all projects (SCOS, MAPCD, PTA, CVE, EPM, CEAV, MMPTA, SMH)
Futurety	Strategy/Planning, Digital Analysis and Audience Segmentation, Paid Digital Management/Optimization, Website Development, Tool Integration/Automation, Database Development & Visualization, Analytics	Recruiting and adoption for CVE, MMTPA, SMH, EPM

Name	Competencies	Projects
Paul Werth	Strategy/Planning, Messaging, Copywriting, Graphic Design, Video Capture and Editing, Grassroots Engagement, Crisis Communications	Recruiting and adoption for CEAV, MMTPA, SMH
Fahlgren Mortine	Website Development, Survey Development	Recruiting and adoption for CEAV, CVE
The Columbus Partnership	Branding, Brand Awareness, Events, Smart Columbus Live (awareness building presentation), Conference Management, Conference Sponsorship, Smart Columbus Experience Center (public education and meeting space), National Public Relations, Local Public Relations, Social Media Management, Website development[27]	Smart Columbus Program

Source: City of Columbus

The following tools and subscriptions were needed to support the communication and outreach work:

- Project Management Tool (e.g, Monday – Privately leveraged)
- Content Management System (e.g., Drupal)
- Customer Relationship System (e.g., Insightly)
- Email Marketing System (e.g., Mailchimp)
- Google Suite (e.g., Analytics, Data Studio, Documents, Drive, Sheet, Forms)
- Online Survey Response tool (e.g., SurveyMonkey or Google Forms)
- Integration/Automation tool (e.g., Zapier)
- QR Code Analytics tool (e.g. QR Code-Generator.com – Privately leveraged)
- Media Mention Tracking and Media Contact Database (e.g., Cision – Privately leveraged)
- Internal Communications tool (e.g., Slack – Privately leveraged)
- Short Link Creator tool (e.g., Bitly)
- Social Media Management (e.g., Sprout Social)

[27] *These efforts and items from The Columbus Partnership were part of their key leveraged partner contribution.*

3.2.2. Audience

Audiences were different for each project. However, in general the communications team considered the needs of the following audiences when planning project-level communications:

- **End users/participants –** People the project was designed to serve
- **Community advocates and champions –** Community leaders or members who were personally or professionally invested in the success of the projects, and were connected to different constituencies that could benefit from the projects
- **Partners –** Organizations that had a contracted role in the project/program
- **Shared learning community –** peer cities, smart city industry, professional organizations, and researchers

3.2.3. Key Strategies and Tactics

The communications team built a communications plan that was aligned with the goals of each project. Details on the audiences, messaging, strategy, and tactics for each project can be found in each project's chapter. Below are factors that were considered when developing the appropriate communications plan for each project:

- **Captive versus public audiences –** The program communications goal was to get as close as possible to one-to-one communication with each end user. These targeted, "captive" end users were reached by working with organizations that had direct relationships with targeted end users. This allows the communications effort to be leaner than had input been solicited from more public audiences. For example, with the Mobility Assistance for People with Cognitive Disabilities (MAPCD) project, there were a handful of organizations that worked with the cognitively impaired population directly. The communications team leveraged those relationships to recruit participants. Similarly, to determine the transportation challenges of pregnant individuals, the team asked groups who worked with this target population to allow the team to conduct focus groups at one of their meetings. More mass media communication tactics were not needed in this case.
- **Location –** Some of the projects were very localized, such as the Linden LEAP service; other projects were regionwide, such as the Pivot app, which included the entire COTA transit service area. Location is a factor when determining a communication plan because it allows use of specialized communication channels like a neighborhood newspaper or billboards. Understanding location also helps determine if there are any cross-promotion opportunities in an area via churches, community organizations, etc.
- **Current transportation habits –** It is helpful to understand the population's current transportation habits to determine which projects are the most relevant and beneficial to participate in. For example, if a person only uses the bus to get around, the Connected Vehicle Environment project is likely not of interest to them. In nearly every gathering during the ConOps development process, potential end users were asked for their input on their current travel habits and challenges. Secondary research that analyzed current transit ridership and safety trends in the project areas were also consulted to further identify challenges and project needs.
- **Level of behavior change –** If a project requires only minor changes in travel behavior, awareness-building communication activities alone may be sufficient to garner participation. If a project requires a significant level of behavior change, more experiential or low-risk trial communication activities and incentives may be needed to get people to participate. For example, if someone already uses multimodal mobility options or already rides the bus, getting them to use the Pivot app may be easier than for someone who drives a vehicle everywhere they go. Conversely, encouraging someone to

install something on a vehicle requires significant effort for the participant. Thus, a financial incentive was added to increase participation.

- **Level of trust –** Understanding the audience's level of trust with the technology or organization leading the project is helpful to determine what potential barriers need to be overcome or mitigated to obtain participation. It is also helpful to identify people, groups, or organizations that have a high degree of trust in the community and work with them to share information with their constituency. The communications team included two Linden-based liaisons to provide credibility and transparency in this Columbus neighborhood, where several projects were deployed. Additionally, the City of Columbus Department of Neighborhoods, Central Ohio Transit Authority, The Ohio State University and countless other project partners were eager to assist in communication efforts as needed. This extended the level of trust and outreach effort immeasurably.
- **Level of engagement in community –** Special considerations need to be made if trying to reach disenfranchised populations. Where traditional communication methods may not work, it is best to identify individuals and speak with them directly about how they get information and adapt tactics appropriately. The communications team worked closely with faith leaders, non-profit organizations and social service agencies. They provided guidance on how best to engage their constituents and allowed the communications team to convene end-user focus groups at their sites. They also shared project information and encouraged their customers to take surveys and attend public meetings.
- **User feedback –** Professionals drafted communications before sharing with end users or consultants who represented end users to ensure communications resonated with target audiences. Messaging was also tested via social media to determine which messages performed the best. Resources were reallocated into top-performing messaging.
- **Data analytics –** Data analytics plays a pivotal role in a digital campaign. The challenge of engaging a diverse population is understanding the variables and use cases that will drive adoption among a wide range of demographic or geographic groups. Geography and demographics play a large role in how people perceive and interact with their mobility. Understanding these differences in populations through analysis of publicly available data can help communication teams create targeted, impactful messages that resonate with target audiences and drive sustainable growth and adoption. Data analysis allows us to understand the human behind the project and what their needs, wants, and motivations are. Dialing those factors into the messaging, allows the team to reach people with messaging that relates to them, and in turn, creates a connection between the message and the solution.

Figure 3-3 shows the overall communications phases.

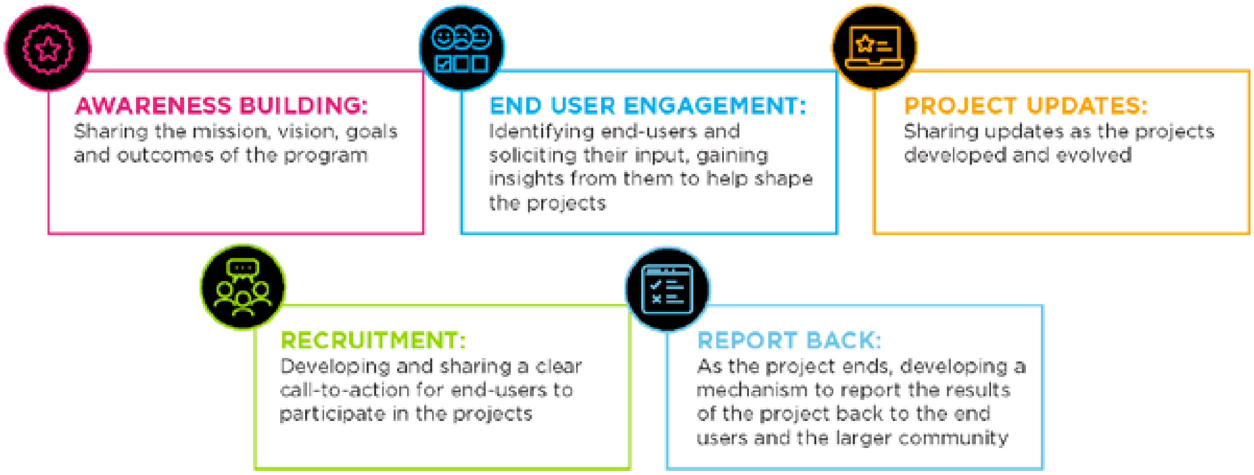


Figure 3-3: Communications Phases

Source: City of Columbus

Each project used the following tactics to the degree that was appropriate for the project. Overall, paid tactics were used at a higher rate to compensate for reduction in shared opportunities (namely community and in-person events) due to COVID-19.

- **Paid:** Paid media includes the development of content that the project paid to be distributed or promoted by someone else. Examples of paid media included:
  - Google ads, geo-fenced digital ads, social media ads/boosted/promoted posts
  - Ads in apps including apps like Waze, Pandora, Hulu or Spotify
  - Paid advertisements on local radio stations
  - Paid advertisements in This Week News and minority publications such as Columbus Minority Communicator and Columbus Black
  - Out-of-home ads like billboards, advertisements placed in movie theaters, or bench ads
- **Earned:** Earned media includes third-party content development and distribution. Examples included:
  - Print, online, TV or radio stories by local media outlets (via press release or media pitch)
  - Word-of-mouth endorsements from participants in-person
  - Letters to the editor
- **Owned:** Owned media includes creation of content by the City (the owner) and control of the platform on which the content is published. Examples included:
  - Project website
  - Project promotional video
  - Direct email
  - Newsletters

  - Experience Center exhibits and public information
- **Shared:** Shared media describes content created by the communications team that is distributed to an audience via a platform that someone else owns or controls. Examples of shared media leveraged included:
  - Social media (Facebook, Twitter, Instagram)
  - Community events and festivals (presentations, tabling)
  - Trusted messenger communication (word of mouth, email, text, newsletter, meeting, presentation, letter, blog, signage, handout).

3.2.3.1. LINDEN LIAISONS

Given the number of projects deployed in the Linden neighborhood, and working in a historically disenfranchised community, the communications team decided it was important to hire two people from the Linden community to serve as community liaisons assigned to support end-user engagement activities. The Linden Liaisons were responsible for sharing updates about the projects in community meetings, distributing materials to residents, having one-on-one conversations with residents to better understand barriers to adoption, and recruiting residents. They supported five projects that had footprints in the Linden area: Prenatal Trip Assistance, Linden LEAP, Connected Vehicle Environment, Smart Mobility Hubs, and Multimodal Trip Planning Application.

The communications team recommends hiring community liaisons to support outreach and engagement work. Valuable insights were gleaned by their serving as eyes and ears in the community. Often community outreach is done by volunteers who have a high level of recognition and pre-existing relationships in the community. Paying these individuals for this important work allows them to dedicate strategic time and effort, hones or expands their skill set, and helps build trust in the community by demonstrating that the City values the community's input.

3.2.3.2. NEW SALEM COMMUNITY OF CARING DEVELOPMENT FOUNDATION

The Community of Caring Development Foundation is New Salem Baptist Church's non-profit, community development corporation (CDC), operating as the church's community and economic arm. The CDC focuses on social determinants of health as community wealth building, supporting education, affordable housing and individual health and wellness in the Linden area. The organization's mission is to create a connected community, and for more than 20 years it has been committed to investing in the lives of individuals and families, as well as small businesses and community-based organizations in the Linden community. The CDC consulted on five projects that had footprints in the Linden area: Prenatal Trip Assistance, Linden LEAP, Connected Vehicle Environment, Smart Mobility Hubs, and the Multimodal Trip Planning Application. The CDC's participation provided access to the community through a trusted organization. Their insights were invaluable to help identify barriers to participation, develop messaging and strategy, and assist in outreach through community programming.

3.2.3.3. WORKING GROUPS

The Cooperative Agreement required the recipient to assemble two Technical Working Group (TWG)s:

- **Electrification Program –** To facilitate integration of electrification activities within the Smart Columbus demonstration and beyond as appropriate (for example, with the Paul G. Allen Family Foundation grant activities).

- **Data TWG** – To facilitate communications, knowledge sharing, identification of project risks and use of best practices to fulfill requirements around replicability, openness, evaluation and sharing of open, controlled access, real time and archival data (specifically, to enable review and feedback on project deliverables).

At the time of the Cooperative Agreement award, the PMO also created and maintained community involvement through additional working groups with the purpose of engaging with the City's diverse stakeholders to serve as advisors on goals, metrics, budget, policy, operations, end-user needs, deployment strategies, needed adjustments and other project-specific decisions. The structure of these additional working groups began as a way to jump-start the project systems engineering process, create an intentional process for community engagement, and bring together a subset of the stakeholders to help diversify how the project teams approached solving city challenges. There were initially 16 working groups covering all USDOT projects and Paul G. Allen Family Foundation Priorities. These were chaired by City staff external to the PMO, and convened in 2016 and early 2017. The 11 working groups focused on USDOT projects were used to gather user needs and begin concept development; members reflect the diverse groups of stakeholders defined earlier. The 11 initial USDOT-related project working groups included:

- Connected Vehicles (Connected Vehicle Environment or CVE)
- Connected Travelers (Multimodal Trip Planning Assistance or MMTPA and the Common Payment System, or CPS)
- Data and Analytics (Smart Columbus Operating System or SCOS, formerly the Integrated Data Exchange)
- First Mile/Last Mile (Smart Mobility Hubs or SMH)
- Downtown Parking (Event Parking Management or EPM, as well as Delivery Zone Availability* and Enhanced Permit Parking*)
- Smart Streetlighting* (Smart Streetlighting)
- Transit Safety* (Transit Collision Avoidance
- Mobility Assistance (Mobility Assistance for People with Cognitive Disabilities or MAPCD)
- Automated Vehicles (CEAV)
- Truck Platooning
- Smart Logistics* (Oversize Vehicle Routing, Interstate Truck Parking)

**Denotes working groups/projects that were removed from the final Smart Columbus Program portfolio.*

The Data TWG met consistently from the time of the Cooperative Agreement initiation through mid-2020, although the structure and purpose evolved over time. Other working groups were added or retired as needed during later phases of the project, noted as "TWG segments," described below:

- **Segment 1 –** August 2016 to December 2017; consisted of 11 subgroups specifically discussing the data-related needs for the program portfolio at the time (connected vehicles, downtown parking, connected travelers, first mile/last mile, smart streetlighting, transit/pedestrian safety, mobility assistance, automated vehicles, truck platooning, smart logistics, and data and analytics (i.e., the integrated data exchange)).
- **Segment 2 –** January to December 2018; sought to gather stakeholder input regarding data stories for the SCOS, policy development around data and data sharing, productization (considerations, cost factors, sustainability and success factors) of a data exchange, and technical best practices for data management architecture, tools, and operational procedures.

- **Segment 3 –** January to December 2019; continued the policy track from Segment 2 (but with a focus on implementation of the policy roadmap, revisions of the Data Management Plan (DMP) and Data Privacy Plan (DPP)) and a new focus on the technology and build out for the Operating System, specifically related to how the SCOS should release to open source, build community engagement, and implement licensing.
- **Segment 4 –** January to July 2020; continued both the technology and policy tracks. The technology track transitioned to identifying user features for entrepreneurs and non-profit organizations while the policy track iterated on data management and privacy best practices, and revised the policy roadmap to reflect these learnings.
- **Segment 5 –** June to July 2020; wrapped up the Technology track, providing engagement with the open-source community on the use of the Elixir programming language to contribute to the SCOS.

The electrification working groups are not listed here, as these were conducted and managed under the leadership of the Paul G. Allen Family Foundation grant, and their outcomes are not actively reported in USDOT Cooperative Agreement deliverables. As the project-level working groups contributed to the user needs for the USDOT projects, the electrification working groups helped to deliver on the Paul G. Allen Family Foundation grant priorities, as it was recognized that progress in the electric vehicle (EV) market required a great deal of stakeholder and consumer education. The Paul G. Allen Family Foundation project team incorporated best practices and data analysis while leveraging partnerships with vehicle manufacturers, dealers and current EV owners to ensure a multi-faceted approach and enhanced EV value perception. The electrification working group included subject matter experts and partners to ensure that the Smart Columbus initiatives were responsive to stakeholder and end-user needs, to provide advice on project-specific decisions, and build relationships to enhance participation, performance and sustainability of the overall program.

Overall, the community of working group members for the USDOT portfolio of projects comprised over 250 people from over 50 organizations. Each working group was provided a focus, hypothesis or challenge, and gathered subject matter experts from the community and businesses aligned to the current phase of the project. The working groups held recurring meetings (bi-weekly or monthly) to maintain engagement and focus that evolved with the needs of the project, which ensured valuable and consistent contributions.

3.2.4. Key Messages

The Smart Columbus communications team developed the following messaging for the SCC and the projects:

- USDOT pledged $40 million to Columbus as the winner of the SCC. By challenging American cities to use emerging transportation technologies to address their most pressing problems, USDOT aimed to spread innovation through a mixture of competition, collaboration, and experimentation. The Challenge called on mid-size cities to do more than merely introduce new technologies onto city streets. It called on them to boldly envision new solutions that would change the face of transportation in our cities by closing the gap between rich and poor, capturing the needs of both young and old, and bridging the digital divide through smart design so that the future of transportation meets the needs of all city residents.
- As the winner of the SCC, Columbus seeks to demonstrate and evaluate a holistic approach to improving transportation through technology. Columbus intends to address how emerging transportation as well as data, technologies and applications can be integrated with existing and new systems to address transportation challenges. Columbus will help define what it means to be a “smart city” and become the country’s first to fully integrate a breadth of innovative technologies including intelligent transportation systems, connected vehicles, automated vehicles, a Smart Columbus Operating System and other advanced technologies into the transportation network.

When developing messaging it was important to focus on the problem, how the Smart Columbus Program proposed to address it, and tie the solution to a visionary end state. It was helpful to create groupings of projects within the portfolio to help residents understand their differences, as well as manage expectations for the projects. Projects funded by the USDOT Cooperative Agreement were organized into the three themes (except for the SCOS, which serves as the data “backbone” for the other projects). These three themes were described in **Chapter 1** and include Enabling Technologies, Enhanced Human Services, and Emerging Technologies (see **Figure 1-1**).

3.2.5. Communications Recommendations

Delivering a diverse portfolio of projects over five years presents communication challenges. Below are recommendations based on that experience:

- Include a communications and engagement professional who can provide oversight and build an appropriate team to meet the communication and engagement goals throughout the program.
- Identify people or organizations in the community who are already doing work that aligns with the project and contract with them for their expertise and insights.
  - Leveraging these trusted messengers was a key tactic. Local and federal governments are not always the most trusted messenger for certain stakeholders, and therefore alternatives should be identified and used to help overcome these challenges.
- Ensure the communications team is closely embedded with the technical team to confirm communication and end-user engagement milestones are accounted for in the overall project plan and schedule.
- Engage end users throughout the project development and find opportunities to co-create with residents.
- When working with disenfranchised populations, it is important to meet people where they are. That may mean going to a community dinner or to the hair salon, or communicating through a church, organization or individual within the community. Find ways to coordinate with other things happening in the community to prevent meeting and survey fatigue from residents. It is also important to ensure the proper supports are in place to help get representational attendance at meetings; for example, providing food, childcare, or bi-lingual and hard of hearing support.
- The engagement of these communities was extremely important in building awareness and trust with the community long before the projects launched and was equally as important as the engineering aspects of the projects.
- Plan regular communication touchpoints with key stakeholders to better manage project expectations as projects evolve and maintain engagement throughout the project lifecycle. People liked to see the impact of their time and efforts. Some tactics used included:
  - For the working groups, a segment report-out process was used to share outcomes with members and enabled a pride in their work and understanding of how their efforts were implemented. In addition, any way in which volunteers wanted to contribute was welcomed, although classified appropriately.
  - Reporting back to the community to explain how their input was used was critical. This was done through e-newsletter articles, presentations and a final report to the community.

- Because volunteers can burn out, causing participation to wane, the working groups used smaller segments with defined outcomes and schedules, which created a path for participants to engage in alignment with their interest, expertise and schedules. This also led to other multiple opportunities for leadership within the community, helping to reduce drop-off in participation. **Figure 3-4** outlines the level of engagement for the TWG members.

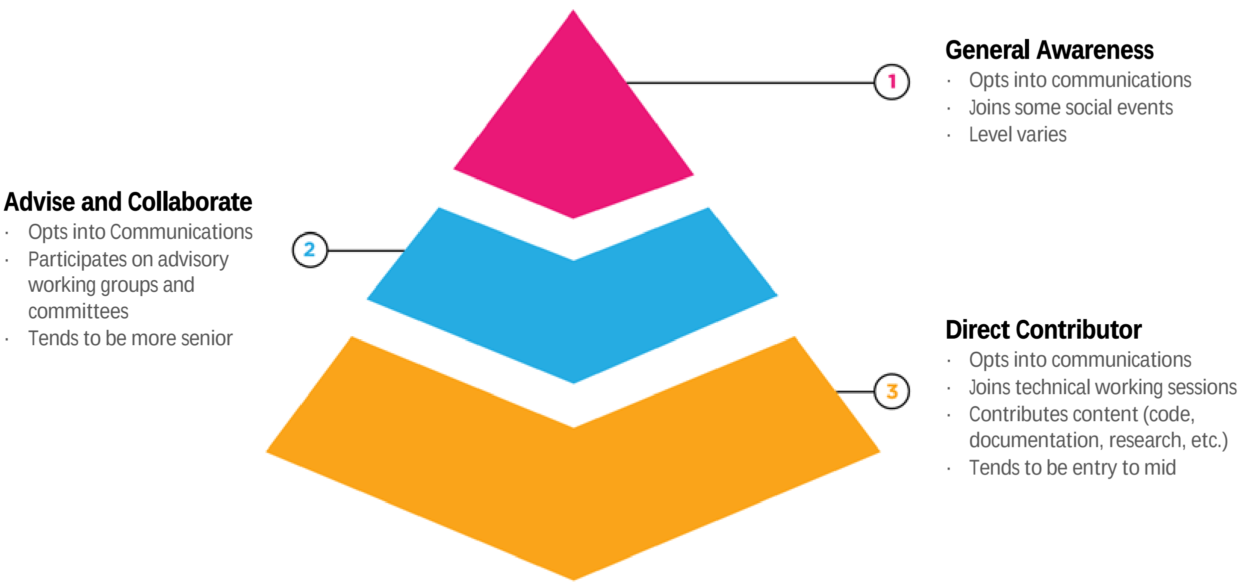


Figure 3-4. Data Technical Working Group Levels of Engagement

Source: City of Columbus

- Use a multichannel, integrated communication approach, when appropriate. This included not only residents, but partners as well. Communications to both residents and partners require planning and resources and are equally critical to success. The resource allocation is distinctly separate because it requires the communications teams to talk about projects from two very different angles.
- Coordination is required to get stakeholders to share your message and content, but the impact is significant compared with other communication tactics.
- Community issues not directly related to the project will arise at stakeholder and outreach meetings. Build mechanisms to ensure those issues are shared with the appropriate City contacts.
- Leverage private sector assets, when possible.

3.3. DATA MANAGEMENT, SECURITY AND PRIVACY

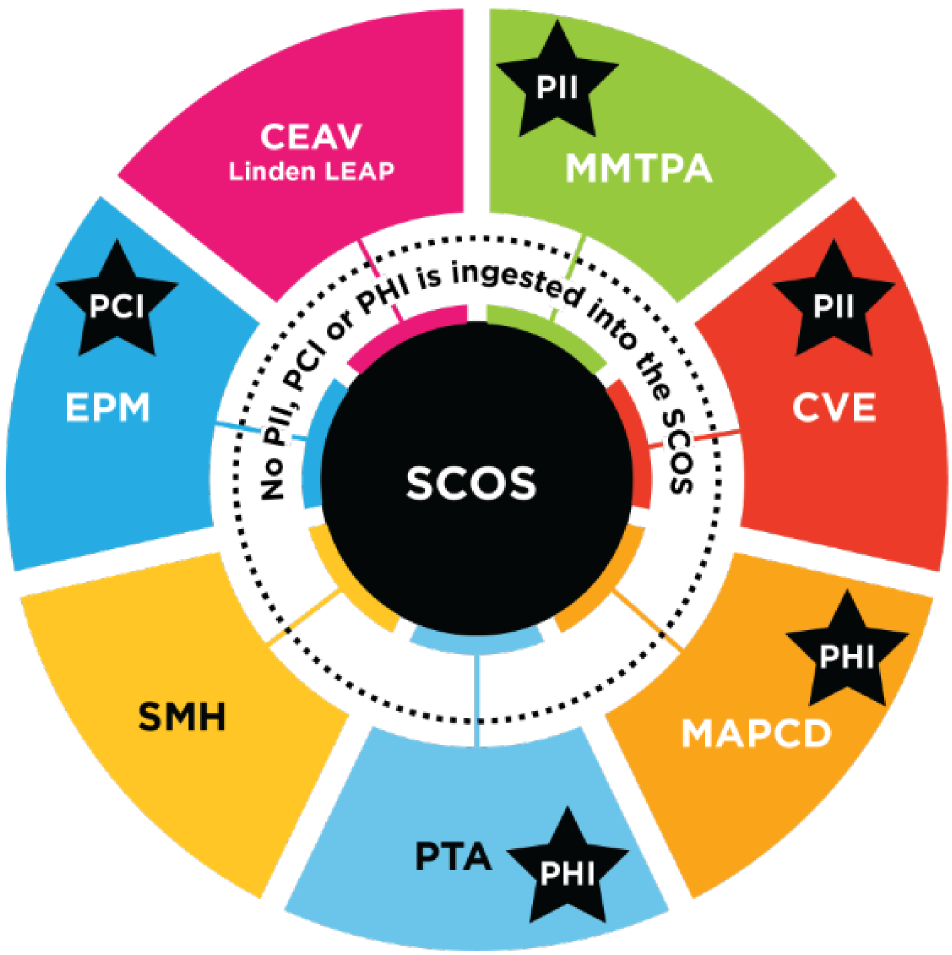
The Cooperative Agreement established the initial security and privacy requirements for the program. USDOT understood that personal data is key to making informed policy decisions, and that it may drive use and operation of Intelligent Transportation Systems (ITS) and smart city technologies. USDOT also understands that the collection, retention, or other processing of data as part of Smart Columbus places accountability on the City. Policies and staffing structures to support privacy protection had to be carefully crafted because of the de-centralized nature of the Smart Columbus Program, with its numerous partners, including USDOT, the City of Columbus, researchers, and vendors with program- and project-level responsibilities. The security and privacy program had to ensure that all parties processing Personally

Identifiable Information (PII) understood their responsibilities. Ultimately, trust had to be extended to program partners for meeting their commitments. However, it is important to note that there are ways, mainly contractual, for holding the organizations accountable for proper processing of PII.

The following elements comprised the Smart Columbus Program Security and Privacy Governance Process:

- **Plans and processes**
  - Establishing the requirements and expectations for security and privacy on a program and project level through the DMP, DPP and related policies
  - Implementation of these plans and policies through governance and data curation
- **Leadership**
  - Guidance and oversight on a program level
  - Program and project management
  - Chief Security Officer (CSO)
  - Chief Privacy Officer (CPO)
  - Data Curator
- **External advisors**
  - The policy track of the Data TWG (as described in the previous section) and later the Privacy and Security Board
  - External thought leaders, accountability, and public engagement

Many program partners handled lower risk data such as limited PII or non-PII. Security and privacy resources were focused on those who had PII and prioritized activities with program partners who had higher risk data, such as Protected Health Information (PHI) and data subject to the Payment Card Industry (PCI) data security standard. **Figure 3-5** shows the projects identifying those with higher risk data categories such as PII, PCI and PHI.



LEGEND

CEAV: Connected Electric Autonomous Vehicle
CVE: Connected Vehicle Environment
EPM: Event Parking Management
MAPCD: Mobility Assistance for People with Cognitive Disabilities
MMTPA: Multimodal Trip Planning Application
PCI: Payment Card Industry
PHI: Protected Health Information
PII: Personally Identifiable Information
PTA: Prenatal Trip Assistance
SCOS: Smart Columbus Operating System
SMH: Smart Mobility Hubs

Figure 3-5: Identification of High Risk Data by Project

Source: The City of Columbus

The Smart Columbus Program security and privacy requirements implemented key controls designed to ensure all parties understood their security and privacy responsibilities and were held accountable if they were processing PII. These controls were:

- Contracts between entities requiring DMP and DPP compliance
- The governance process and Privacy Impact Assessments (PIA)
- The data curation process and de-identification policy
- Institutional Review Board (IRB) oversight (discussed later in this chapter)

3.3.1. Plans and Processes

The USDOT Cooperative Agreement outlined the requirement for the DPP and DMP. The Data TWG iteratively developed and implemented the plans based on the USDOT Cooperative Agreement, USDOT guidance, relevant laws and guidelines, and the participants of the Data TWG. The plans, combined with the policies described below, effectively served as the Smart Columbus information security policy and the overall governing documents for security and privacy.

- The DPP provides high-level guidance, principles and policies to ensure the privacy of Smart Columbus Demonstration data subjects and project participants. This document applies to all individuals who use or share data with the SCOS, including all employees, partners and consultants.
- The DMP documents how the data within the SCOS will be added, made accessible or stored within the SCOS platform. It details how the data will be created, captured, transmitted, maintained, accessed, shared, secured and archived.

Additional policies were created to supplement the DMP and DPP including:

- Data Access and Correction Policy
- De-Identification Policy[28]
- Law Enforcement Data Access Policy
- SCOS Website Privacy Policy
- SCOS Terms of Use
- Public Records Retention Schedule

3.3.1.1. GOVERNANCE

While the focus of the governance process was on the entities who collect, transmit, store, or otherwise process PII on behalf of the program, a meeting was held with almost every other vendor and researcher working on the Smart Columbus Program so that they were aware of applicable privacy and security obligations. These meetings covered:

- Contractual requirements to follow DMP and DPP
- Awareness of the DPP and DMP
- Awareness that the SCOS will not accept PII
- Privacy Impact Assessments (PIA) based on the flowchart in **Figure 3-6** for all companies processing data containing PII
- Documentation of the activities in an “Assessment Summary” document

[28] https://www.smartcolumbusos.com/images/Assets/SCC_De-Identification_Policy_20190917_update.pdf

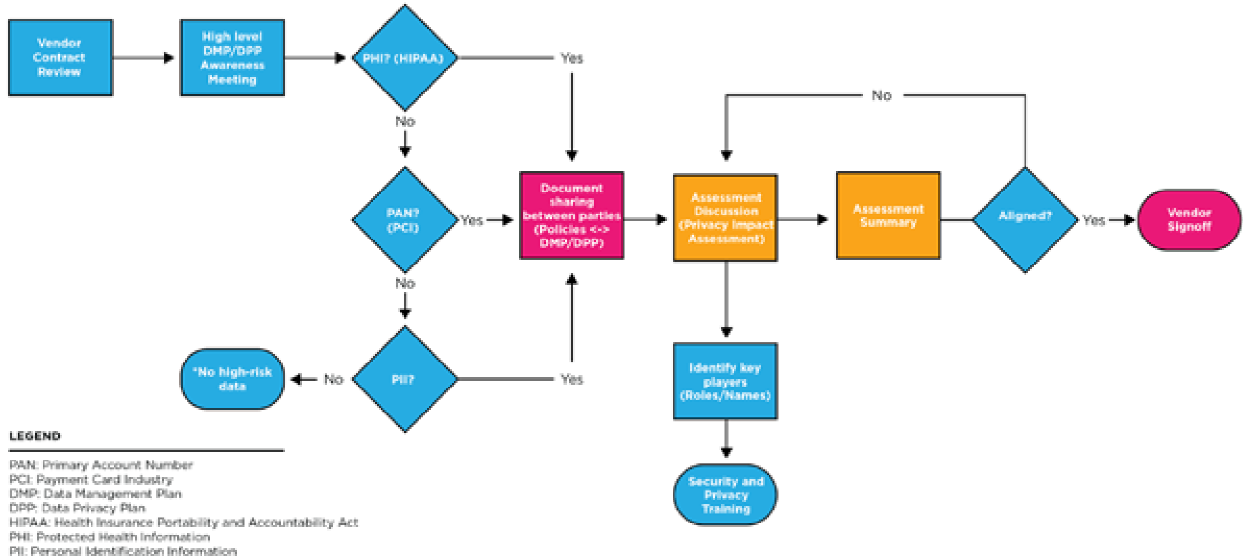


Figure 3-6: Smart Columbus Program Risk Governance Process

Source: The City of Columbus

3.3.1.2. LEADERSHIP

The Smart Columbus PMO established the roles of Chief Security Officer (CSO) and Chief Privacy Officer (CPO) to ensure independent oversight of these functions. These roles were defined in the process of implementing the data management and privacy plans and were added to the PMO (the CSO in 2019, and the CPO in 2020) and staffed by individuals external to the City. The CPO is responsible for the sustained viability, compliance and oversight of data privacy policies and processes. The CSO is responsible for the design, implementation and oversight of the information technology and physical security of the program and its project components.

Additionally, the CSO and CPO managed security and privacy training. They ensured that any Smart Columbus personnel or individuals who have access to PII (such as software developers, system testers and project managers) completed required training covering the privacy and security policies, procedures, and requirements of the DPP and related documentation.

3.3.1.2.1 External Advisors

As discussed in the Working Groups subsection above, the second iteration of the program working groups included a policy track to help guide and inform data management and privacy documents, policies and leadership for the program. This group consisted of professionals from various backgrounds, including a data privacy law professor, chief privacy officers of large corporations and the State of Ohio, technologists, government officials including a chief information officer and City attorney, privacy attorneys, data management professionals, security professionals, program team members, and many others. The Policy Working Group's task was to create the first drafts of the DMP and DPP with guidance from other USDOT projects, and to support the development and review of later updates as well.

3.3.1.2.2 Privacy and Security Board

While drafting the DPP, the Policy Working Group and the PMO agreed that the creation of a Privacy and Security Board would be beneficial to the program. While a reduced number of individuals from the Policy Working Group continued to assist the program team as it related to updated versions of the DMP and DPP and related policies, Smart Columbus officially established an independent Privacy and Security Board during the summer of 2020. The Board met quarterly through May 2021 and activities included:

- Obtaining updates from the City, CSO, CPO, and others on recent developments relating to the privacy and security of Smart Columbus and the data it processes
- Providing advice on new developments and emerging best practices in information privacy and security
- Providing recommendations, where relevant, on any modifications to the DPP
- Reviewing annually the results of any audits or assessments conducted through the year

3.4. SAFETY MANAGEMENT AND ASSURANCE

3.4.1. Safety Management

3.4.1.1. ROLE AND RELATIONSHIP TO THE PROGRAM

In accordance with the Cooperative Agreement, the PMO developed the Safety Management Plan (SMP) to identify and document the underlying safety needs associated with the safety of all travelers (including project end users), and other personnel associated with each of the projects in the program portfolio. The SMP provides the systematic approach to achieving acceptable levels of safety risk within the demonstration and does the following:

6. Describes the risk assessment process and approach for the program, including identifying the stakeholders and responders who contribute to the safety related goals and requirements.
7. Identifies the potential safety scenarios and then assesses the level of risk for each scenario for both the program level and the eight individual projects.
8. Defines the mitigation strategies to reduce the likelihood and/or impact of the scenario.

When considering all safety scenarios, the project teams primarily considered the physical risk that the projects were introducing to travelers and participants (in the case of projects such as MAPCD and PTA, where a specific population was recruited to participate in the project's demonstration). This is not to say that cybersecurity risks were not included, but their impact on the physical safety of stakeholders can potentially be less as these could indirectly create a physical risk to travelers. As such, these were documented at a high level for the projects that included a software component and assessed appropriately as having a lower impact on a traveler's physical safety.

An important aspect of SMP development and safety management overall were the stakeholders who were involved in the process and activities. The SMP includes a list of all stakeholders involved in the safety of the individual projects. The stakeholder types that were involved were:

- **Project teams –** Involved in safety scenario development and risk assessment process
- **Partners –** Provided review and validation of scenarios and mitigations
- **Stakeholders –** Those with vested interest in the project development, deployment, or coordination
- **First responders –** Provided validation of proposed mitigations

3.4.1.2. PLANS AND PROCESSES

The process to develop the Final SMP for the Smart Columbus demonstration program was an iterative one. The process began in the summer of 2018 with the initial draft development. At that point in the program, most projects had completed their ConOps or trade studies and had initiated the development of their system or procurement requirements. The PMO also engaged an independent subject matter expert (SME) from Battelle to participate in the risk assessment process. Using these documents, the guidance from USDOT, and connected vehicle (CV) pilot examples available on the CV Pilots website[29], the PMO met with the individual project teams and their stakeholders to brainstorm an initial list of risks. The PMO (led by the safety manager) independently scored each risk in terms of its severity, controllability and exposure against a defined set of ratings. If the level of risk for a particular safety scenario had a medium or high probability of occurrence, the team also drafted a safety operational concept (mitigation) for those scenarios.

These scenarios, ratings and mitigations were reviewed with the stakeholders before completing the first draft in November 2018. This review process was repeated in early 2019, as new vendors had been on-boarded as the projects continued their development and implementation. The final document included the validation that safety related requirements and mitigations that had been implemented in the deployment-related materials that were developed for projects in demonstration (training materials operations, maintenance plans, etc.). The final document published in December 2019 reflected all vendor input following the last of the vendors executing contracts in the summer of 2019.

In conjunction with the final update, the first annual safety review was conducted, and annual safety reviews were also completed in 2020 and 2021. The goal of the annual review was to verify that the safety risks were still applicable (after factoring in any design changes that had occurred), review the implementation of proposed mitigations (as identified in project documentation), and assess whether any new risks had been identified since the project entered demonstration. The safety review also included collection of any documentation for incidents that occurred, ensuring that a post-incident review was completed and stored in accordance with the SMP.

After each project entered demonstration, the Safety Manager for the PMO monitored all projects for the implementation of the mitigations and their effectiveness, as identified in the safety operational concept. Each project manager was responsible for verifying that the mitigation was included in the project-specific documentation or designed into the solution.

Figure 3-7 shows the number of overall risks per project and the number of those risks that required the safety operational concept, where the Safety Manager monitored the implementation of the mitigation.

[29] https://www.its.dot.gov/pilots/technical_assistance_events.htm

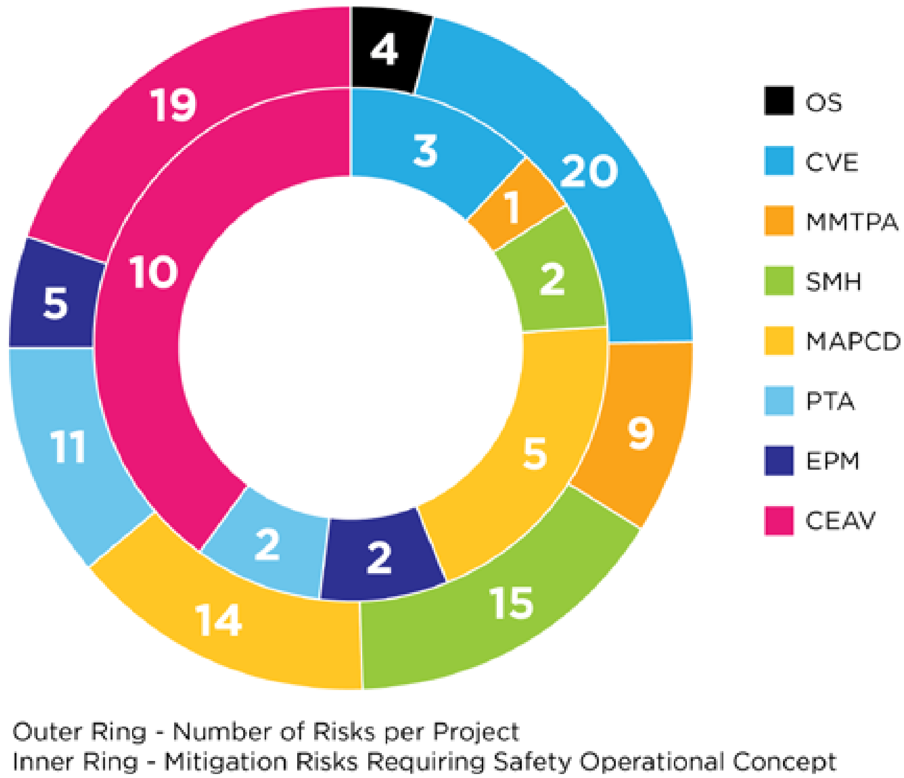


Figure 3-7: Risks by Project

Source: City of Columbus

3.4.2. Human Use Approval

3.4.2.1. ROLE AND RELATIONSHIP TO THE PROGRAM

A critical component of safety management is the protection of the human participants. Oversight by an IRB is one example of an operational concept identified in the SMP. The PMO relied on the IRBs to some extent for each of the projects and for the performance measurement process, which collected survey data from residents in the region.

The PMO published a separate document, the Human Use Approval Summary (HUAS), to capture how IRB oversight was used at the program and project levels during both demonstration and performance measurement. The IRB process ensures that research involving human participants is designed and conducted in an ethical manner and in accordance with applicable laws and regulations, verifies that protections are in place for both participant data and physical safety, and that risks are effectively communicated to these participants.

The HUAS accomplishes the following activities:

- Provides background on the importance of HUA and IRB oversight
- Documents the IRB application and review process from IRB selection through approval, including feedback and revisions
- Describes coordination between IRB activity and other program tasks, including ConOps, System Requirements, and Performance Measurement
- Identifies dependencies, constraints, and key challenges
- Identifies events or situations that could affect potential future IRB activities in the program

The HUAS appropriately references the Smart Columbus SMP, as it provides guidance on identifying safety scenarios and risk mitigations and is closely integrated with the IRB process, usually being attached as a reference. All project-related IRB submissions also included the DMP and DPP as references, since they describe how data is collected, managed, integrated, and disseminated before, during, and after the demonstration. In terms of protection of participant information, the program did not collect, use or share PII without the data subject's knowledge and informed consent. If collected, it was typically to enable follow-up for recruitment or survey purposes; as such, only minimal PII was gathered. It was not stored in the Operating System, but securely maintained and its protections documented in each project's research protocol and communicated to participants through the informed consent process.

3.4.2.2. PLANS AND PROCESSES

The HUA process relies on an accredited IRB to oversee projects involving human research subjects. All eight Smart Columbus Program projects involved human subjects in some way during testing, execution, and performance measurement phases, so all required HUA.

Smart Columbus used both an academic IRB through OSU as well as a commercial IRB (Advarra) for oversight. The determination as to which IRB was used depended on whether OSU was a project partner. Therefore, OSU's IRB was used for the program performance measurement effort, as well as the MAPCD and PTA projects. All other projects used the commercial IRB. Regardless of which IRB was used, the process was the same: the project team developed a research protocol to document the extent of human research participation required, data that was collected from participants (and how it was stored), what risks had been identified to the participant, and whether consent was necessary. For some projects, the IRB would deem the project 'exempt', which indicated the project posed no risk to human participants. In these cases, no consent or additional information was required to be developed or approved by the IRB unless there was a change to the project's interaction with the participants.

For projects that did pose some risk to human subjects (such as CVE) or where the project teams had to regularly engage with recruited participants (also CVE, in addition to MAPCD and PTA), additional documents had to be reviewed and approved by IRB, including informed consent documents, surveys, and any participant-facing information such as recruiting and training materials so they could be approved prior to distribution. Any change to a project's research protocol or participant-facing information required a resubmission to IRB for approval. In addition, once approved, IRB oversight is provided for a period of 12 months. Therefore, some projects, such as CVE, also required a continuation request since participant interaction took place throughout the recruiting and demonstration phases.

The HUAS was updated quarterly to capture all IRB activity across the program.

3.5. PROGRAM MANAGEMENT LESSONS LEARNED

While program management can seem like a series of straightforward processes related to staffing, scheduling and budgeting, the task becomes infinitely more complex when considering it must govern a holistic program of eight individual projects, while working collaboratively with a diverse group of stakeholders and funding partners. The lessons learned captured in this section are specific to the management activities discussed above.

1. **Dedicated staff is key –** Even if an application is a moon shot, an agency should be prepared to win by identifying the right positions and staff as soon as possible. Although the City thought it had made appropriate assignments within the PMO at the time of award, many staff had existing projects and commitments and lacked the availability to fully ramp up early project management and systems engineering activities. In addition, some positions lacked the 'right' expertise. The restructured PMO that was created in 2017 included SMEs in each area (communications, technology, partnerships, finance/procurement) that was necessary to successfully deliver all requirements in the Cooperative Agreement. Although it can seem excessive, a more robust team should be identified early on, and the PMO can flexibly adjust to scale up or down to accommodate the changing needs of the program. The spend rate for the program reflected the slow start by the City to set up and begin work. More funding could have been spent early on to set the program up for success and ensure the right number and type of staff were involved. These activities would have minimized growing pains in working through federal requirements, which ultimately caused the program activity to slow significantly for approximately six months while the PMO was restructured and systems engineering activities revisited. This pause was necessary to ensure that the City maximized the opportunity for success but ultimately could have been avoided if the right people had been in the right seats from the beginning of the program.
2. **Communications was a key activity throughout the Cooperative Agreement –** From the time of award to post-launch of most projects, the benefits of communication to the program cannot be understated:
    a. It was originally envisioned that stakeholder engagement would provide the most value as the projects developed concept and requirements. However, the PMO saw value in continuing end-user engagement as the projects continued through development, testing and launch. Participant recruitment is obviously important, especially for projects such as CVE, MAPCD and PTA, where informed consent is needed, surveys are expected, and frequent interaction is required. It was also important, however, for other projects to maintain communication with the community to educate and prepare them for the technology (such as for SMH and CEAV) and could have been used even more for projects such as MMTPA, where beta testers provided direct feedback to the development team on the performance and usability of the Pivot app.

    b. Coordination and communication at the state and regional level with funding partners is also critical. This coordination and communication helped the PMO to efficiently leverage assets, workforce, and knowledge while achieving interoperability and awareness for many of the projects. Forward focused projects may also require regulatory/policy changes that can only be driven at the state level. Good examples of this coordination include:

        i. The coordination between the City and DriveOhio to implement certain CVE system components including position correction and the security credential management system (SCMS).

        ii. The first CEAV deployment with May Mobility, which was co-led by DriveOhio, The Columbus Partnership and the City. DriveOhio led the procurement effort, scope development, and contract conditions, while the City managed the day-to-day operations after the vendor was selected.

        iii. For the second CEAV deployment, the City used the lessons learned from the first deployment to create a more robust RFP and requirements, while DriveOhio remained as an engaged stakeholder, providing permitting and regulation for the vehicle's operation in Linden.

3. **The pace of public procurement is not always in line with technology –** The City of Columbus procurement process is about five months long, from drafting the request for proposal (RFP) through to the Notice to Proceed (NTP) issuance, and reflects not only the procurement and selection, but also the legislation and City Council approval and contracting process with the vendor. All procurements for services, equipment and software for the program had to follow this process. In several cases, the City was able to expedite the procurement timelines and perform the process in about three months. While timelines can be expedited, the City still had to be cognizant of City Council meeting dates and breaks, and other impactful events that were beyond the control of the PMO, and could cause delays to a vendor's NTP (and ultimately, delays to deliverables and key project milestones).
   - While the majority of the consultants and vendors who supported the Smart Columbus Program were competitively selected, there were a few examples where sole source selection was used. The primary example was with the selection of AbleLink as the MAPCD vendor. In this case, the City's sole source procurement rules were followed. Some projects were able to leverage vendors and products that had been competitively selected in previous contracts (such as the selection of ParkMobile for EPM).

3.6. PROGRAM FINANCIALS

As with all projects, the investment required to deliver them is always of great importance. The USDOT SCC was no different and was primarily funded by federal, state and local contributions. The SCC program was delivered with cash and direct contract investments from USDOT, the City of Columbus, the Ohio Department of Transportation, Franklin County and The Ohio State University (OSU). This section summarizes the program funding by source, as well as the changes to the budget from the time of award to final demonstration. This section also presents the allocation of the program budget, breaking out deployment costs from operations costs. The high-level budget per project is also shown, with additional detail contained in each project's chapter.

Key leveraged contributions from private sector, non-profit and other public agencies are also presented separately, also within each project's chapter as appropriate. These funds were committed during the application phase and refined as necessary to meet program needs as determined by the PMO. Not all key leveraged partner contributions were used by the PMO, and these do not contribute to the final program budget.

3.6.1. Funding Sources

The Cooperative Agreement between the City and USDOT was executed using the budget submitted in response to the USDOT solicitation. The Cooperative Agreement also called for annual budget reviews and program plans due 60 days prior to the anniversary of the agreement. Therefore, each year, on or before June 30, the PMO submitted an updated program budget that reflected scope changes (e.g., removal of Truck Platooning), revised project estimates, revised cost-share partner contributions, revised personnel estimates and any other known changes to the budget.

The initial program budget was estimated at approximately $59 million and reflected "cost-share" (non-federal) contributions from the City of Columbus, ODOT, and Franklin County to various projects and efforts in the program. OSU later became a cost-share partner, but was not added to the budget until 2019, which is why they do not appear on in **Figure 3-8**, which depicts the originally proposed program budget.

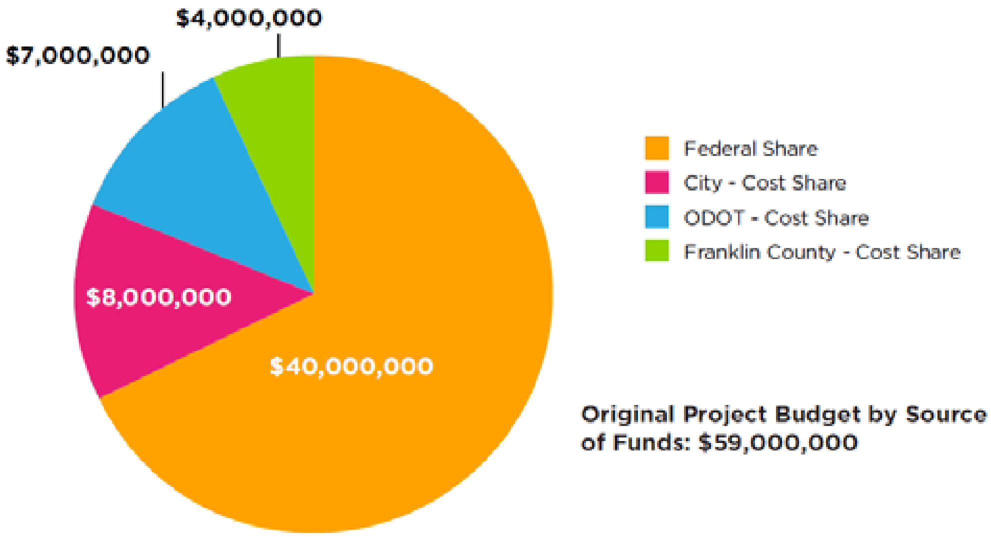


Figure 3-8: Original Program Budget by Funding Source

Source: City of Columbus

Over the course of the program, the budget was revised multiple times to reflect scope changes in the Cooperative Agreement or in the individual projects. The next section contains a summary of each revision. The final budget for the program was approximately $54.6 million, a breakout of these funds by source is shown in **Figure 3-9**, with OSU included as an additional cost-share partner. Additionally, ODOT's cost-share contribution was reduced as the extent and scope of partner contributions was clarified after award. Ultimately, because the City was responsible for the cost-share portion of the agreement, their cost-share was increased to cover misaligned contributions from other cost-share partners.

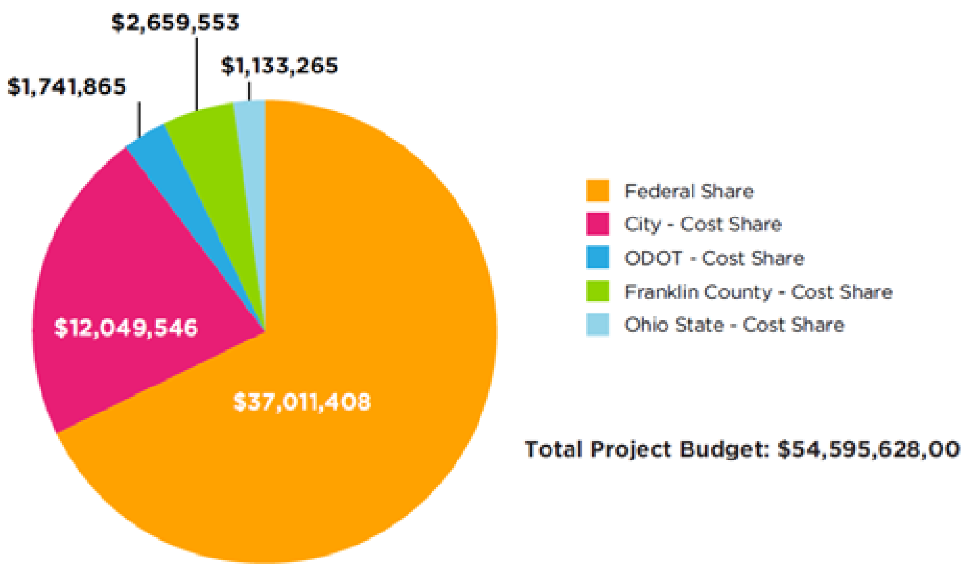


Figure 3-9: Final Program Budget by Funding Source

Source: City of Columbus

3.6.2. Approved Budget Changes

As discussed in the previous section, the approved program budget evolved over the course of the award period. A summary of these changes are captured in **Table 3-3**, which provides detail regarding the specific amendment to the Cooperative Agreement, the date of the change and the scope reduction that it reflected. The two major changes that resulted in budget reductions were the removal of the Truck Platooning and Common Payment System projects. The technical rationale for the removal of these projects is discussed in **Chapter 2**.

Table 6: Summary of Budget Changes by Amendment

Amendment	Date	Description of Changed	Revised Total Budget
Original Award	8/30/16	N/A	$59,000,000
4	5/27/19	Decrease the value of the agreement by $3,137,325 (which consists of a decrease in federal share of $2,127,000 plus a decrease in nonfederal share of $1,010,325). Related to removal of the Truck Platooning project from the agreement.	$55,862,675
7	9/17/20	Decrease the value of the agreement by $1,267,047 (which consists of a decrease in federal share of $861,592 plus a decrease in nonfederal share of $405,455). Related to removal of the Common Payment System project from the agreement.	$54,595,628

Source: City of Columbus

3.6.3. Key Leveraged Partners

Key Leveraged Partners provided third-party resources in support of the demonstration, as specified in the Cooperative Agreement. USDOT considered these resources to be essential to the demonstration and were thus approved and incorporated into the award. Although the contributions of these key leveraged partners are not tracked and accounted for as part of the overall budget, the City did track and report the status of these agreements to USDOT through the quarterly progress report process. Therefore, adding or removing a key leveraged partner required approval from USDOT through an amendment to the Cooperative Agreement. As with the overall program budget, the contributions of these partners evolved during the demonstration. **Table 3-4** summarizes the final list of partners, an estimate of their contribution (as some were made through in-kind contributions or work that did not require invoice submittal/approval to the City). The table also captures a brief description of the work that was done. In the case that the work directly supported a project, these contributions are also noted in the project chapter with a brief description of the work.

Table 7: Summary of Contributions by Key Leveraged Partner

Partner	Program or Project	Description	Estimated Amount
AT&T	Program	Ÿ Security testing with CVE Ÿ Working with airport to use video analytics to make de-icing less manual and predict vulnerabilities in perimeter Ÿ Data sharing Ÿ Telecommunications support at the Experience Center	$1,000,000
AWS	SCOS	Currently hosting SCOS	$1,000,000
Battelle	SCOS	Development and data curation	$1,000,000
The Columbus Partnership	Program	Continuing program staff support and private sector in-kind	$10,000,000
Continental	Program	Equipped two traffic signals to broadcast “ghost” BSMs for pedestrians and vehicles; developed dashboard to review signal information	$1,000,000
COTA	Program	In-kind staff to support multiple projects, including CVE, SMH, PTA, MAPCD, and MMTPA	$9,000,000
Econolite	CVE	Installing firmware and analytics software licenses and support equipment	$280,000
Franklin County	CVE	Alum Creek corridor for CVE operation	$2,000,000
Greater Columbus Arts Council	Program	Investment to support communication, education and awareness of smart city programs	$1,000,000
Honda	CVE	Working on providing CV data to SCOS from 100 vehicles equipped with onboard units (OBUs)	$2,600,000
INRIX	Program	Traffic data for Performance Measures	$1,424,000
ODOT	Ÿ SCOS Ÿ CVE	Continued staff support and data services for Smart Columbus	$1,741,865
Sidewalk Labs	PTA	PTA-related research and concept development	$230,000

Source: City of Columbus

As the SCC was a first-of-its-kind initiative, there was an immense amount of interest in being part of this program. During the application phase and immediately following award, there were many expressions of interest in supporting the program. In-kind commitments to the program were very much appreciated by the City of Columbus and the commitment of in-kind investments by national and local partners were key to the City winning the SCC. Commitments brought to the table by USDOT and the City's application package were numerous. In all cases, the City worked with USDOT to track potential and executed agreements. If the offer did not align with public procurement rules or could not be incorporated into the program delivery or aligned with the program, then the contribution was removed. USDOT established a process for removal based on justification provided by the PMO.

3.6.4. Deployment and Operations Budget

This section presents the final budget of $54,595,628 in terms of deployment costs (e.g. systems development and unit costs) and operations and maintenance costs. Deployment activities included all program initialization, systems engineering, performance measurement planning, communications and program management activities from the time of award up through August 2020, when a majority of the projects had entered demonstration (and for projects such as CVE, construction was completed). Program management, communications and performance measurement data collection and analysis that took place after September 1, 2020 have been allocated to the operations and maintenance category. Additional project-level cost detail for both deployment and operations and maintenance are highlighted in each project's chapter, along with the contributions of any key leveraged partners.

As noted above, program-level deployment costs include all activity from award through August 2020, with program operating costs covering spending from September 2020 through the end of March 2021. September 1, 2020 was selected as the dividing line between deployment and operations for the program as a whole because a majority of the projects were in demonstration by that point, and for those that were not (EPM and CVE) they had completed a majority of deployment and testing activities by that point. At the project level, deployment costs include all activity from award up to the individual launch date for that project. Project-level operating costs include costs incurred after the launch date through March 31, 2021. Therefore, the table includes a column for funds unspent as of April 1, 2021.

Operations and maintenance costs include all City, consultant and vendor costs to operate and maintain the projects, support post-launch communications and performance measurement data collection, conduct performance measurement analysis, plan for the sustainability and transition of the projects post-demonstration, and provide final report information to USDOT.

The following figures and **Table 3-5** provide the total program and project costs broken out by these two categories.

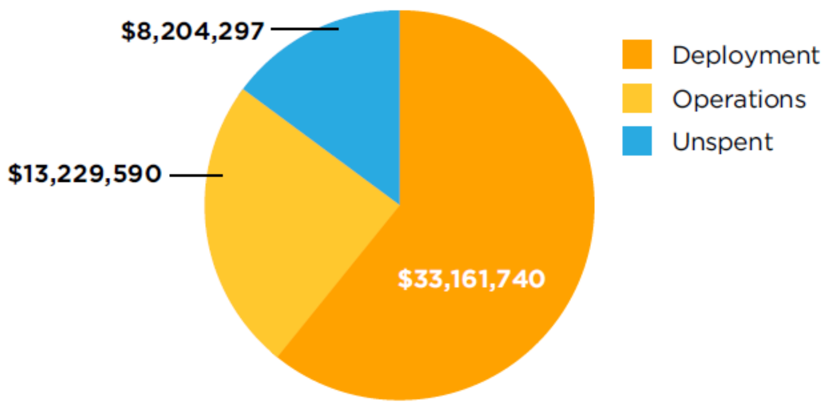


Figure 3-10: Overall Program Costs (Program and All Projects)

Source: City of Columbus

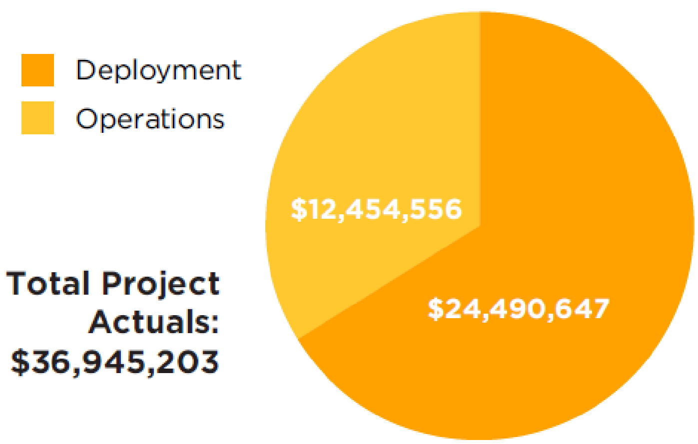


Figure 3-11: Total Costs of All Projects (Excluding Program Costs)

Source: City of Columbus

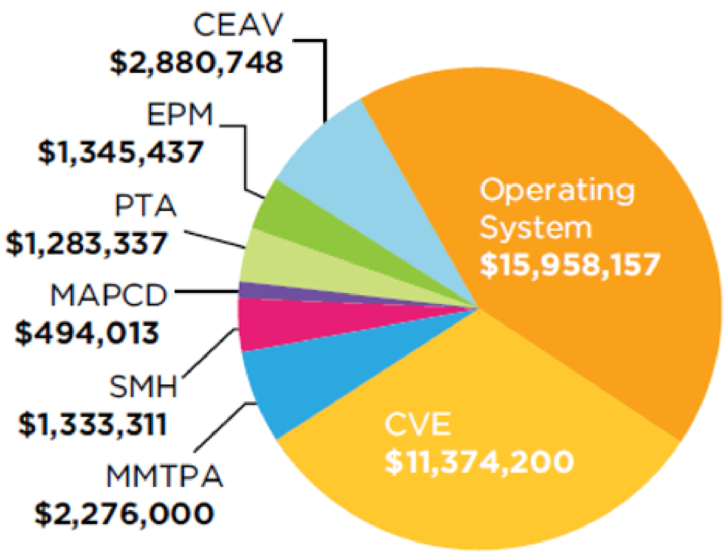


Figure 3-12: Total Cost Per Project

Source: City of Columbus

Table 8: Total Program Costs by Category

Category	Deployment	Operations	Unspent	Total
Program	$8,671,094	$775,034		$9,446,128
Total Project Cost	$24,490,647	$12,454,556		$36,945,203
Unspent			$8,204,297	$8,204,297
Total	**$33,161,740**	**$13,229,590**	**$8,204,297**	**$54,595,628**
		Project Breakout Costs		
SCOS	$8,038,495	$7,919,662		$15,958,157
CVE	$9,770,937	$1,603,263		$11,374,200
MMTPA	$1,891,788	$384,212		$2,276,000
SMH	$1,008,140	$325,171		$1,333,311
MAPCD	$260,886	$233,127		$494,013
PTA	$531,528	$751,809		$1,283,337
EPM	$1,068,238	$277,199		$1,345,437
CEAV[30]	$1,920,634	$960,113		$2,880,748
Total	**$24,490,647**	**$12,454,556**		**$36,945,203**

[30] *CEAV project costs include all project related work regardless of the location (i.e., planning work for Easton, the May Mobility deployment on the Scioto Mile and the EasyMile deployment in Linden).*

Source: City of Columbus

Figure 3-13 illustrates the program management costs required for a project of this scope, with breakouts by deployment and operations; **Figure 3-14** and **Table 3-6** break out the costs by vendor.

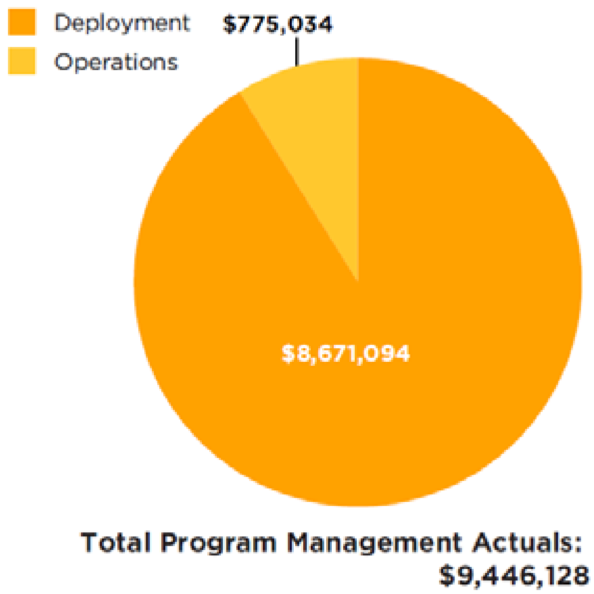


Figure 3-13: Program Management Costs

Source: City of Columbus

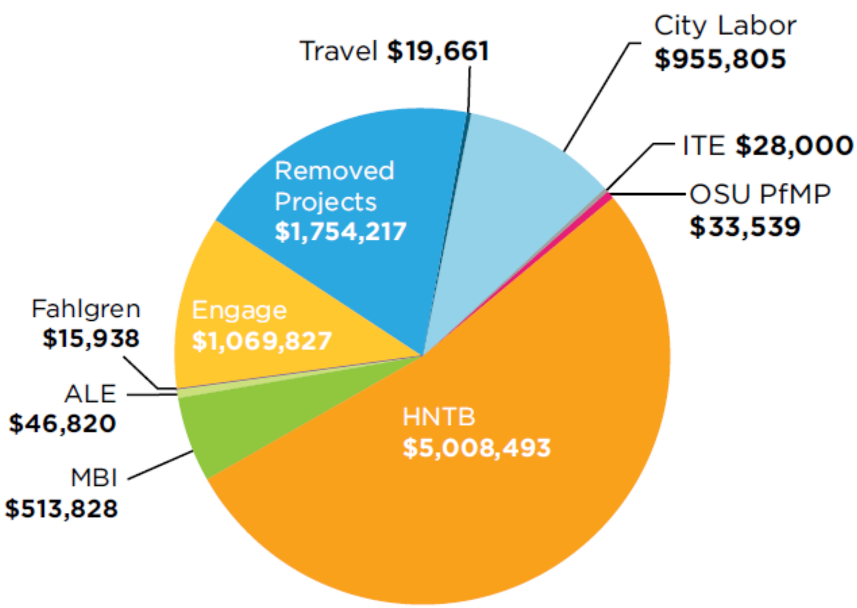


Figure 3-14: Program Management Vendor Actuals

Source: City of Columbus

Table 9: Program Management Costs

Vendor Actuals	Deployment	Operations	Total
City Labor	$846,888	$108,917	$955,805
ITE	$20,000	$8,000	$28,000
OSU Performance Measurement Plan (PfMP)	$33,539	-	$33,539
HNTB (WSP, CCI, Advarra)	$4,490,674	$517,820	$5,008,493
MBI (Taivara)	$426,607	$87,221	$513,828
ALE	$46,820	-	$46,820
Fahlgren	$1,906	$14,031	$15,938
Engage (Murphy Epson)	$1,030,781	$39,046	$1,069,827
Removed Projects	$1,754,217	-	$1,754,217
Travel	$19,661	-	$19,661
Total	**$8,671,094**	**$775,034**	**$9,446,128**

Source: City of Columbus

3.6.5. Financial Lessons Learned

Managing eight projects in varying stages of deployment, as well as numerous contributing partners, created challenges for the City. Lessons learned regarding managing partner commitments, and the difficulty with keeping cost estimates updated, are described below.

- **Managing partner commitments –** While critical to the project, navigating in-kind, and even cash commitments from partners can be challenging. Specific lessons learned around the funding sources and how they were spent are outlined below:
  - Cost-share funding was the most reliable source of the three types of funding, although the rate of spending sometimes varied outside projections. In the final budget, about $17.6 million in non-federal cost-share funds were allocated to the program. These were a combination of City, state, county and university funds. Except for county funds, all funds were in-kind or direct contracted investments by the cost-share partner for the purpose of program delivery. For instance, Franklin County provided $1 million cash to the program and the Franklin County Engineer's Office provided about $1.7 million of in-kind direct contracts to deliver the connected vehicle project. City funds allocated to the program were bond funds, which can only be used for capital spending (borrowed funds can't be used for operating expenses). While bond funds largely aligned with program needs, the PMO discovered that operating funds were needed to execute work like communications and other non-bond-eligible activities. Because the program was being executed with City of Columbus, Department of Public Service staff and funding, the PMO was able to work with the Public Service Finance Director to align program funding needs with the correct funding source.

- Leveraged partners as identified in the Cooperative Agreement were the most difficult to use. The City's application package listed about $90 million in estimated contributions alone, of which about $44 million was allocated to the USDOT Cooperative Agreement and $53 million allocated to the Electrification Program. Ultimately, in-kind contributions were challenging to align with the program delivery as partners often had specific solutions and the PMO was working to identify the system requirements through the systems engineering process or the offers were contingent upon additional payment by the City. Some key leveraged partners made their offers through in-kind commitments; however, these offers came with the requirement of additional funds being spent by the City. In-kind commitments that required City investment to leverage still had to meet the scrutiny of public procurement and being a good value to the program. In most cases, the City had to forego the offers of leveraged in-kind contributions.

- **Keeping project estimates updated –** Estimating costs is challenging in all projects but becomes an art for new and innovative technology projects. Estimates should be developed and revisited throughout the project development process. As the PMO worked to align the funding needs of the program, good project estimates became essential. While costs were regularly updated as invoices were received and reimbursements processed, overall program estimates were revisited annually in May to include all known information (for example, partners that joined or left the project) and appropriate contingencies to manage and mitigate new and emerging risks. These estimates were discussed with the team and incorporated into the revised program budget each June.
  - Obtaining valid implementation estimates for all projects was very important, however, estimates for technology projects must also include development, testing and support during the demonstration. Technology solutions varied widely in technical specifications and costs. Understanding each project's user needs allowed the project teams to draft system requirements, as a standalone systems engineering document or as part of the scope of services in the RFPs. Prior to procurement, the project teams also researched various solutions for all the projects; having these cost benchmarks from other cities, transit agencies and states allowed the teams to check and refine the estimates as needed.
  - Ultimately, strong project estimating using an iterative process that aligned with the annual program budget updates led to a successful budgeting strategy that allowed the PMO to stay within budget.

3.7. SUMMARY

The delivery of the USDOT SCC demonstration relied on several major program management pillars. The City used the structure suggested by USDOT in the Cooperative Agreement to deliver the program, while managing the systems engineering task at the project level. Program-level items included program management (including budget), performance measurement (discussed in **Chapter 4**), data management and privacy, safety management and assurance (including IRB), communications and outreach, and reporting (including this final report, as well as quarterly reports to USDOT). The complexity of this structure created some challenges as staff and project teams had to manage both the individual projects and contributions to the overall program. Overall, though, this structure resulted in consistent guidance to the project teams on the topics covered by the Cooperative Agreement tasks and a more cohesive and integrated program portfolio.

Chapter 4. Performance Measurement Findings

4.1. INTRODUCTION

The primary objective of the Smart Columbus Program was to demonstrate, quantify, and evaluate the impact of advanced technologies, strategies, and applications toward addressing the City's challenges. The performance measurement findings help clarify the impact of the integrated smart city solutions on the six program outcomes: safety, mobility, opportunity, environment, agency efficiency, and customer satisfaction. The purpose of this chapter is to present a summary of key findings from the performance measurement, particularly those that speak to the momentum of the Smart Columbus Program's projects, and those which can inform other demonstrations and deployments. The full performance measurement results can be found in the Performance Measures Results Report on the Smart Columbus Program website.

In addition to results for outcomes and objectives identified in the Performance Measurement Plan (PfMP)[31] (**Section 4.2**), researchers at The Ohio State University (OSU) conducted several supplementary analyses on the economic, accessibility and housing impacts of the Smart Columbus Program. These findings are not included in the Performance Measures Results Report, as they are outside its scope, but are presented here in **Sections 4.3, 4.4 and 4.5** respectively.

4.1.1. Approach

The Smart Columbus Program PfMP was based on U.S. Department of Transportation (USDOT) recommended best practices for performance measurement. It uses a diagrammatic logic model for each program-level outcome and project-level objective, identifying outcomes and objectives, the treatment to achieve the project objectives, a hypothesis (and assumptions) about how the objectives could be met through the treatment, and the indicators to measure the performance. An overview of the logic model and description of each element is provided in **Figure 4-1**. Key insights from the logic model with results were then used to develop the key findings, described for each outcome in **Section 4.2**.

Outcomes	Objectives	Treatment	Hypothesis	Outcome Indicators	Results by Indicator
Specific Program Outcome	Specific, measurable impact intended	Treatment used to achieve the desired objective	Testable assertion about the way in which a project will impact an indicator.	Measurements that will change over time (before, during and after implementation) or compared to a control group to test validity of the hypothesis.	Results by indicator including number of results, comparison of results, and interpretation of results.

Figure 4-1: Logic Model Overview

Source: City of Columbus

31 https://d2rfd3nxvhnf29.cloudfront.net/2021-04/SCC-C-PfMP-Update-v3%203.30.21.pdf

4.2. PERFORMANCE MEASURES: RESULTS BY OUTCOMES

The Smart Columbus Program established a vision, mission, and six outcomes for the Smart City Challenge. The outcomes are shown in **Figure 4-2** with the projects that contribute to them. This figure displays the potential impact of solutions developed to address challenges facing the City of Columbus, including traffic congestion, crashes, infant mortality, poverty, and unemployment.

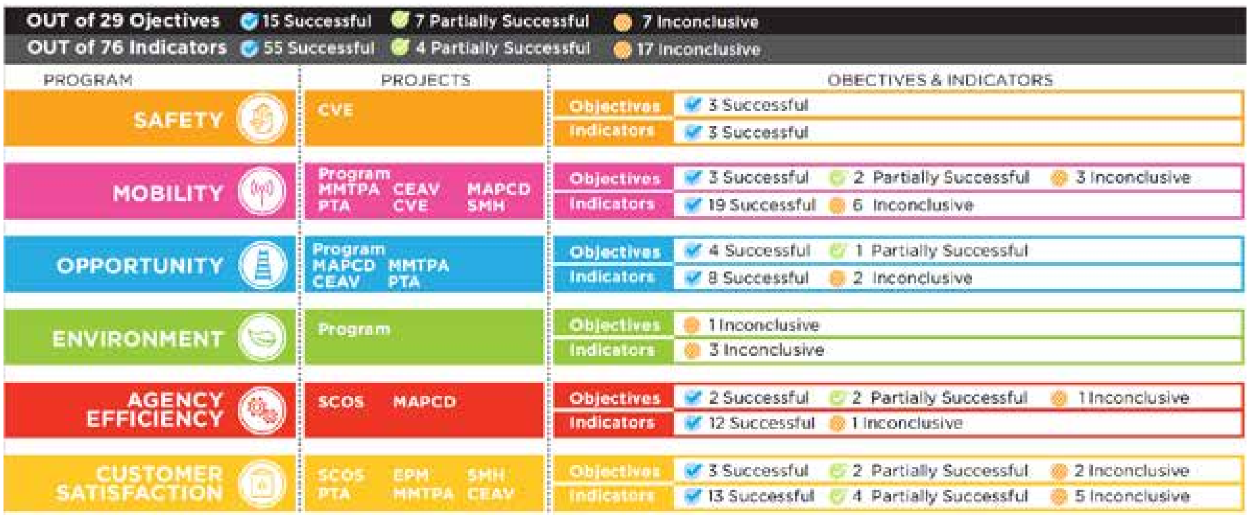


Figure 4-2: Smart Columbus Program Outcomes

Source: City of Columbus

Note: "Program" refers to outcomes in the PfMP that were measured cumulatively at the program level rather than the project level.

Findings for each of the six outcomes are described in the sub-sections below.

4.2.1. Safety

The Smart Columbus Program aimed to improve safety by reducing transportation-related fatalities and injuries and improving the response times of public safety vehicles (e.g., ambulances). The Connected Vehicle Environment (CVE) project was the only project that was measured against this outcome, specifically in terms of three connected vehicle applications: emergency vehicle preemption (EVP), red light violation warning (RLVW) and reduced speed in school zone (RSSZ). **Figure 4-3** summarizes key highlights against the safety-related objectives from the Performance Measurement Plan. All three objectives for this outcome were successfully achieved:

- Emergency response times improved when preemptions were granted
- Drivers were more aware of red lights and slowed down approaching intersections, especially when warnings were received farther from the intersection and vehicles were moving faster (more than 20 mph)
- Compliance with school zone speed limits improved from 18% to 56%

These CVE applications did what they were intended to do – test the technology, validate the hypotheses in the logic model, provide insight into how to maximize benefits, and build awareness of the technology in the community. This demonstration also built a foundation for scaling up CVE technologies in the future.

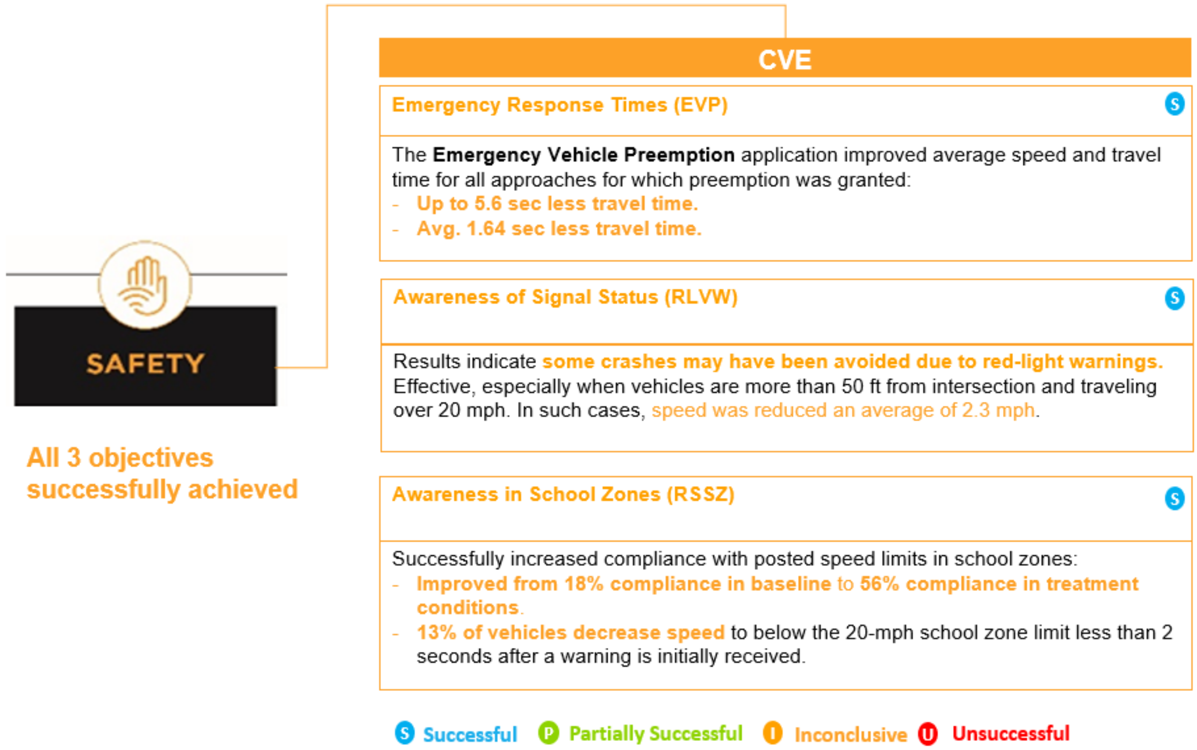


Figure 4-3: Smart Columbus Program Safety Objectives and Key Highlights

Source: City of Columbus

4.2.2. Mobility

The Smart Columbus Program enhanced the city's mobility by deploying projects that include improving access to transportation services and multimodal trip planning and reducing roadway and parking congestion. Despite significant COVID-19 pandemic impacts on travel, ranging from reduced congestion and parking demand to policies that travel be limited to only essential trips, the Smart Columbus Program was able to demonstrate partial or full success on five out of its eight mobility objectives. Three objectives had inconclusive results due to sample size and COVID-19 impacts. Key mobility outcome highlights by project are shown in **Figure 4-4**. Several insights that can inform continued deployment and/or scale-up include:

- Multimodal Trip Planning Application (MMTPA) allowed users to compare and select multiple travel options and itineraries and provided a method to analyze user data to improve the app. More widespread use could facilitate a shift away from single occupancy vehicles (SOVs) at a time when projected population growth will further strain the city's transportation infrastructure.
- Smart Mobility Hub (SMH) usage was very limited during the demonstration period (eight trips, accounting for only 2% of trips planned with Pivot) but may increase after the COVID-19 pandemic or in warmer months when more people may be willing to use scooters, bikes or walk.
- For the Mobility Assistance for People with Cognitive Disabilities (MAPCD) project, although the team attempted to recruit existing paratransit users, none were willing to participate, possibly indicating hesitancy around change or new technology, which could inform future marketing and training efforts.

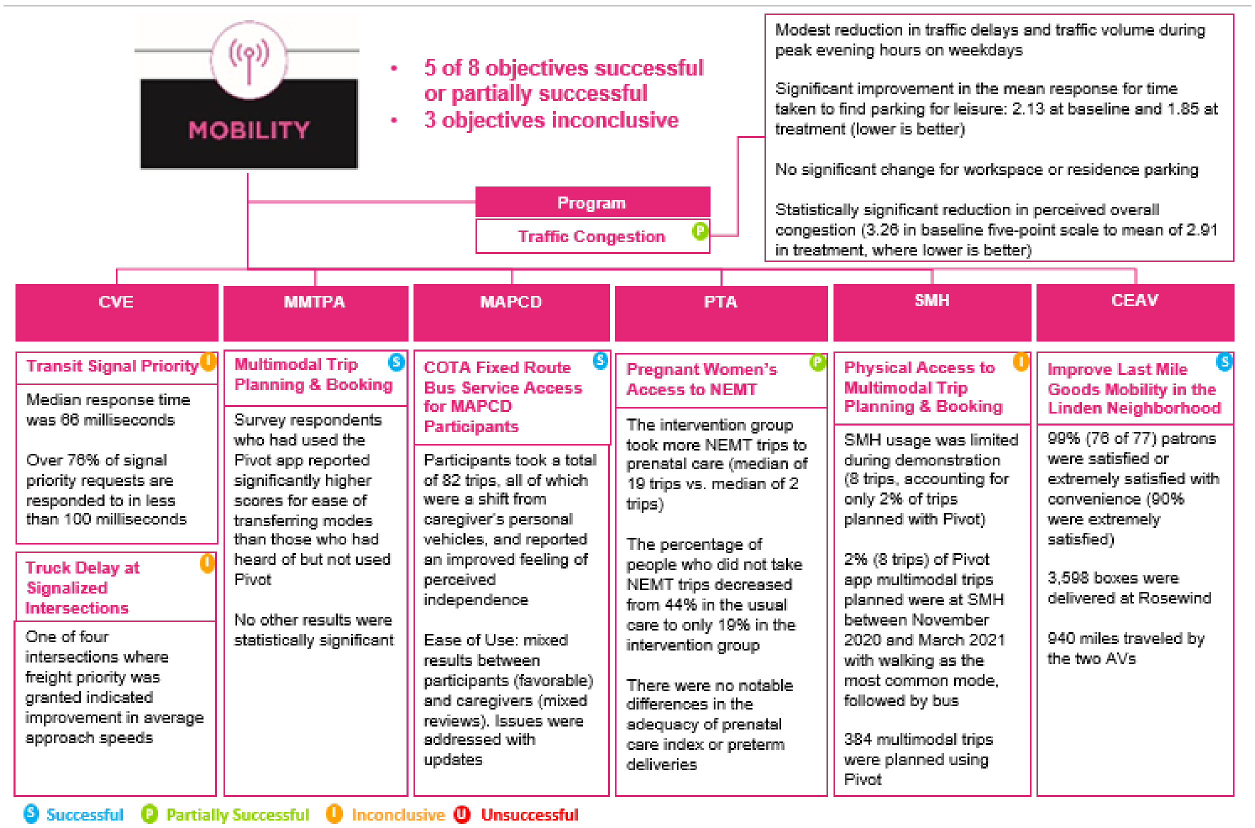


Figure 4-4: Mobility Objectives and Key Highlights

Source: City of Columbus

4.2.3. Opportunity

Providing improved access to transportation options for Columbus residents was a key goal of the Smart Columbus Program. This outcome aimed to increase access for underserved communities to a wide variety of services through transportation solutions focused on improved access to places of employment, education, health care, and other services, as well as increasing the use of the shared transportation network by bringing available services and users together.

Specifically, the Smart Columbus Program created opportunity by addressing the barriers that travelers face with existing transportation systems. This included facilitating multimodal trip planning by allowing travelers to have a comprehensive view of transportation service options available to them, enhancing and demonstrating a smartphone app that helps people with cognitive disabilities achieve mobility independence, and streamlining access to non-emergency medical transportation for pregnant individuals. As shown in **Figure 4-5**, all five objectives for the opportunity outcome were achieved with full or partial success. Key insights:

- Survey respondents reported a significant increase in access to health care and entertainment after implementation of MMTPA (Pivot) and a marginal increase in ease of getting to work.
- MAPCD participants achieved a feeling of improved independence as the WayFinder app gave them the support needed to travel on fixed route bus service alone, without having to rely on a ride from caregivers, friends or family.

- The Prenatal Trip Assistance (PTA) project provided more efficient, on-demand transportation to non-emergency medical treatment (NEMT) trips for Medicaid recipients, facilitating more usage of NEMT trip benefits.
- The Connected Electric Autonomous Vehicles (CEAV) shuttles helped mitigate the first mile/last mile transportation obstacle by bringing food pantry boxes near the Rosewind Community Center, making it easier for many food-insecure residents to access the food they rely on. This was especially important during the pandemic when food pantry demand increased and there was hesitancy or inability to ride public transportation or get rides from friends and family without risking COVID-19 exposure.

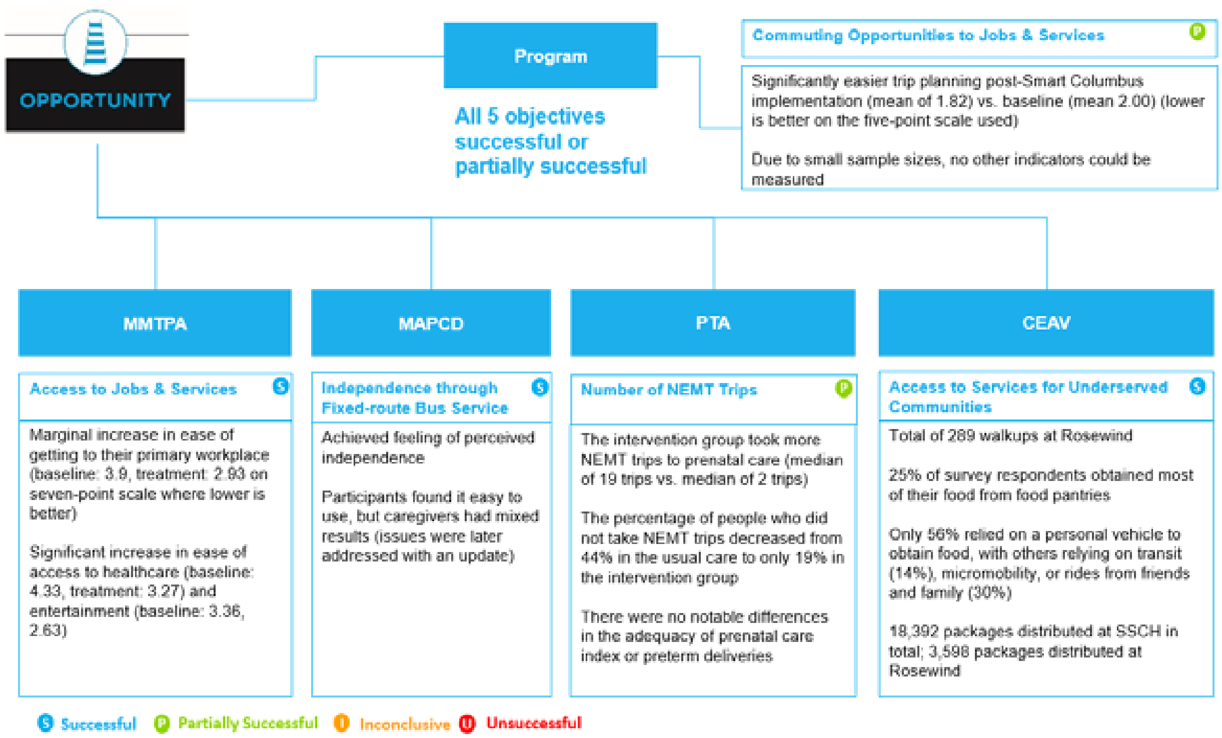


Figure 4-5: Opportunity Objectives and Key Highlights

Source: City of Columbus

4.2.4. Environment

The Smart Columbus Program reduced transportation's negative impacts on the environment through implementing advanced technologies and policies that support a more sustainable transportation system. For example, MMTPA encouraged many shared-use and transit-related services that shift travelers away from single occupancy vehicles (SOVs). CVE Signal Priority (especially freight signal priority) provided opportunities to reduce truck-related emissions and save fuel. Additionally, Event Parking Management (EPM) was designed to reduce parking congestion by making it easier to find and take a direct route to parking (thereby reducing emissions from driving around looking for parking).

Due to small sample sizes and the impacts of COVID-19, results were inconclusive in terms of greenhouse gas savings[32] (see **Figure 4-6**). This was not, however, due to a failure of the applications, technologies, or project teams. Despite not being measurable during the demonstration period, the intended environmental benefits of implementing the Smart Columbus portfolio of projects may still be achieved in the future if these technologies become more broadly used.

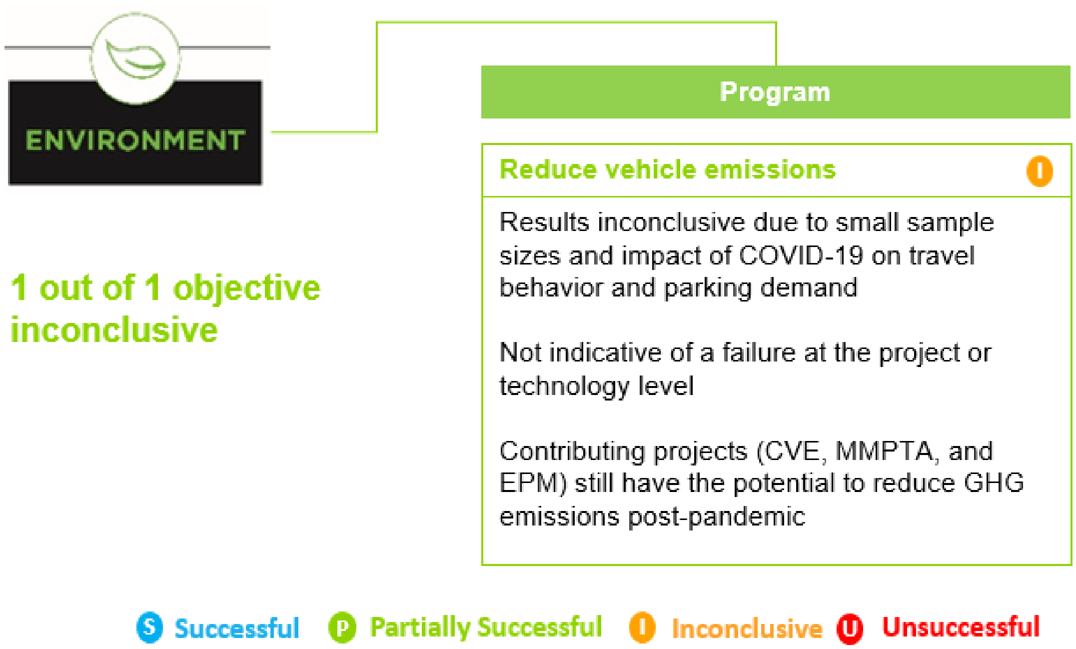


Figure 4-6: Environment Objective and Key Highlights

Source: City of Columbus

4.2.5. Agency Efficiency

The Smart Columbus Program improved the ability of government, transportation, and community agencies to provide services to residents through advanced technologies. It enabled easier access to real-time data, streamlined internal processes to improve communications and information sharing, and made internal agency operations more efficient. For example, implementing the Smart Columbus Operating System (SCOS) provided a method to share data and improve efficiency within user agencies by supporting communications and facilitating the usage of data in agency programs more effectively and efficiently. As shown in **Figure 4-7**, the Smart Columbus Program achieved four out of five of its agency objectives, and one was inconclusive.

[32] *The program-level environmental analysis EPM component was based on the same survey results used for the EPM project results, which were inconclusive regarding potential reduction in time and distance to find parking. The program-level mobility outcome was evaluated with a separate survey including questions regarding parking, which showed a significant reduction in time to park for leisure activities and entertainment. This survey was designed for a different purpose by a different research team, with survey questions tailored to mobility indicators. They were not conducive to analyzing potential greenhouse gas emission reductions, and so were not used for the program-level environmental outcome.*

- During the demonstration period, the SCOS saw over 222,000 downloads and over 67,000 queries, indicating strong interest in accessing the SCOS datasets. Examples include:
  - There were over 55 downloads and close to 50,000 queries performed by external users on the 34 datasets ingested from Parking Services into the SCOS.
  - For the 19 datasets ingested from Central Ohio Transit Authority (COTA), 841 downloads and more than 3,500 queries were performed by the SCOS external users across the same time span. A constant upward trend of queries and downloads of the datasets was observed across both years examined, indicating that the SCOS customers are finding value with the datasets published.
- The MAPCD project was intended to reduce COTA paratransit expenditures by shifting existing paratransit users to fixed-route bus service supported by the WayFinder app. However, this objective could not be measured as existing paratransit users were unable to be recruited to participate. As noted above, this may indicate hesitancy around change or new technology, which could inform future marketing and training efforts.

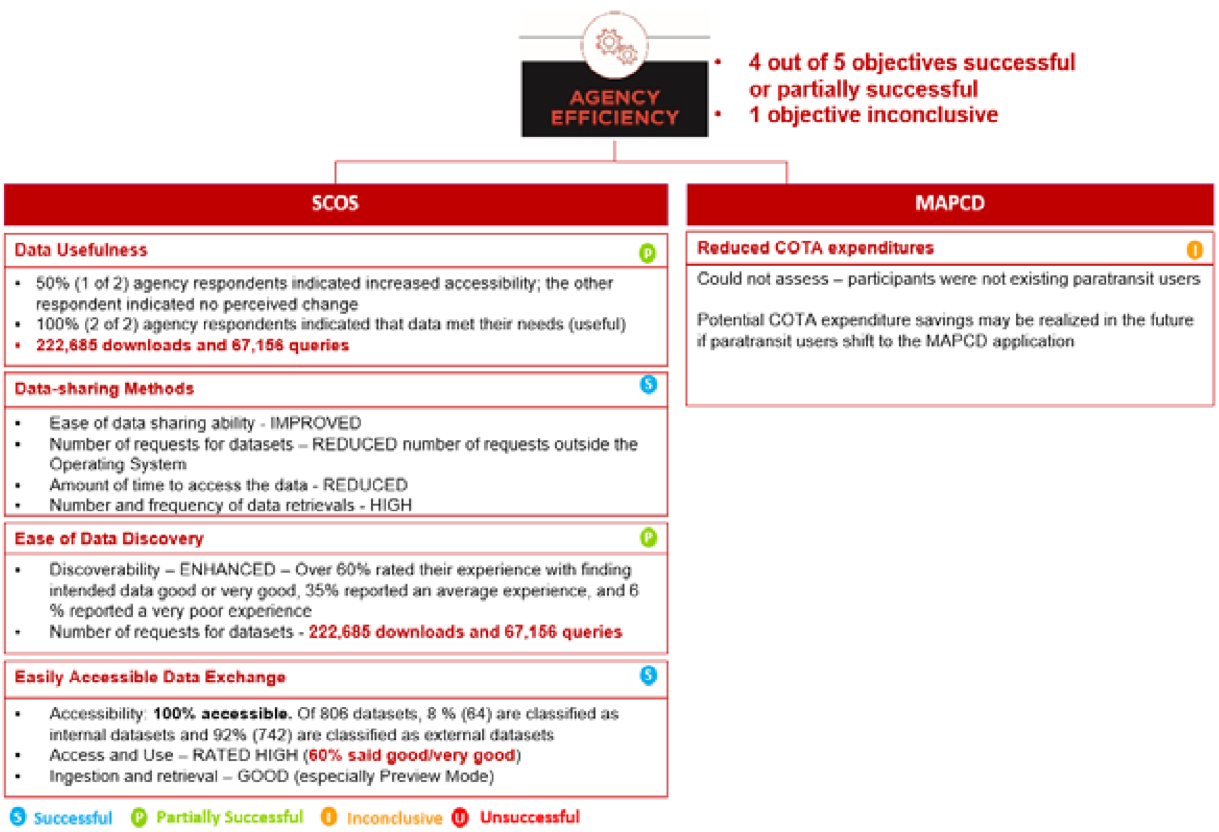


Figure 4-7: Agency Objectives and Key Highlights

Source: City of Columbus

4.2.6. Customer Satisfaction

The Smart Columbus Program aimed to provide services that are useful, easy to use, and embraced by the community. By implementing advanced technologies such as MMTPA or SMH to help travelers reach their destinations, the products and services supplied by the City met or surpassed a traveler's expectation. As shown in **Figure 4-8**, the Smart Columbus Program achieved five out of seven customer satisfaction measures, and the remaining two were inconclusive due to small sample size and COVID-19 impacts on travel.

- Customer satisfaction was high across all contributing projects that produced measurable results:
  - **SCOS –** Over 70% responded good or very good for various functions
  - **MMTPA –** Over 97% found Pivot easy or very easy to use
  - **PTA and CEAV –** 90% were satisfied, very satisfied, or extremely satisfied
- Although EPM and SMH did not produce statistically significant results due to small sample size and COVID-19 pandemic impacts on travel and parking, usage may increase when travel patterns normalize when COVID-19 is less disruptive or in warmer months when more people may be willing to use scooters, bikes or walk.

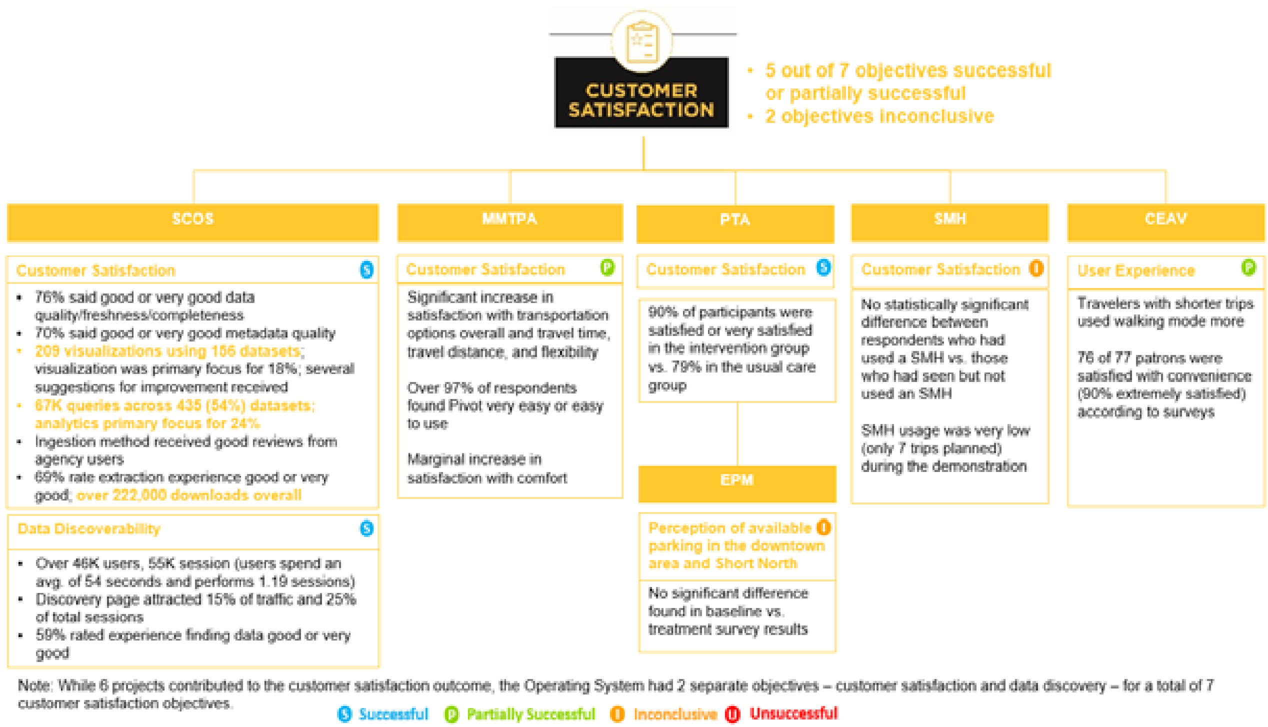


Figure 4-8: Customer Satisfaction Objectives and Key Highlights

Source: City of Columbus

In addition to the projects that had a customer satisfaction objective specified in the PfMP, as shown in **Figure 4-8**, the CVE and MAPCD projects also provided insight into customer satisfaction.

- **CVE –** 62% of private vehicle participants said they would recommend connected vehicle (CV) technology to friends and family. This is a significant endorsement of the technology concept, despite imperfections inevitable in a new application of technology, especially among early adopters. Overall satisfaction levels decreased for both public and private drivers between Phase 1 and Phase 2 surveys, but the shift was largely from the "satisfied" category to "somewhat satisfied" or neutral categories.

- **MAPCD –** Participants received safety, public transportation, smartphone, WayFinder app, and fixed bus route simulation trainings. For each training provided, the number of participants satisfied ranged from 84% to 96%. The result was participants felt more comfortable using public transit as a result of the WayFinder app.

4.3. ECONOMIC IMPACT

One way to assess the impact of a program or project is by calculating the cost-benefit of the demonstration. Notably, this element was omitted from the PfMP because the Cooperative Agreement had included an independent evaluation task as part of Task E, Data Management and Support for Independent Evaluation. The Cooperative Agreement specified that the City's responsibility with respect to this task should include provision of data, performance measures, and participation in evaluation activities such as field visits and tests, surveys and interviews. Interactions with the independent evaluator were initiated in 2018 with an official kickoff in March 2019. In November 2019, the independent evaluation of the program was removed from the Cooperative Agreement; this was memorialized in Amendment 7 in September 2020. By that point, the performance measurement approach had been finalized, with projects either in demonstration or near go-live. Although a robust cost-benefit analysis was not planned, OSU completed an economic analysis of the program with the available project and program financial data.

OSU's analysis considered a broader definition of "smart city" beyond the outcomes that were defined in the PfMP to include economic impact. While extensive studies have attempted to provide an understanding of the smart city fundamentals, there are a few research gaps in the various assessment processes that have been used. First, although many studies have developed various smart city assessment tools, most of them focused on the evaluation of the overall technological performance, whereas there is a lack of assessment from the perspective of economic impacts of the deployed systems. It is also unclear what the inherent mechanism between a smart city initiative and the economic performance is. Second, previous assessments of smart cities (including the overall Smart Columbus PfMP) mainly relied on the indicator approach, which has several major limitations, such as the involvement of subjectivity in terms of the indicator selection, and that the indicators could only be applied in limited cases. The purpose of OSU's cost-benefit analysis was to develop a comprehensive assessment tool to quantify the impact of smart city-related investment and initiatives accurately.

The methodology and findings of this analysis are summarized below, with details available in **Appendix E**.

4.3.1. Methodology

OSU developed an assessment framework of the economic impact of smart city investment using a computable general equilibrium (CGE) model,[33] with the Smart Columbus Program being used as a case study in the model. OSU's research and modeling provides a useful assessment tool to measure the potential economic impacts of smart city investments. Smart city investment generates both short-term and long-term economic effects. The short-run impact analysis focuses on evaluating the economic impact during the project (from 2017 to 2021). The short-run impact on the macroeconomy in terms of changes in the gross metropolitan product (GMP), employment and business revenue was assumed to be achieved through the stimulus effect from the Smart Columbus Program capital investment in the corresponding economic sectors. Long-term effects refer to the economic impact generated from the operation of the systems, which is often manifested by an increase in productivity and travel behavior changes (these should be considered predicted outcomes due to the uncertainty and assumptions that are used in their calculation). The analysis focuses on the local economic impact on the ten counties in the Columbus

[33] *CGE models have been used extensively to assess environmental and economic impacts of transportation infrastructure investment (Chen et al., 2016; Chen et al., 2021; Chen & Haynes, 2014; Hensher et al., 2012).*

Metropolitan Statistical Area,[34] and does not capture any spillover effect on other cities and regions. **Figure 4-9** captures the methodology.

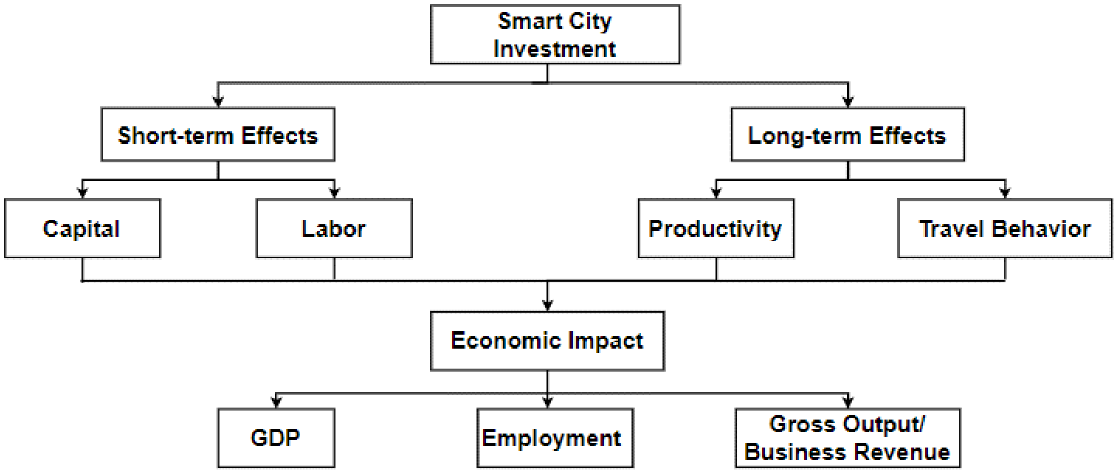


Figure 4-9: The Modeling Framework of the Economic Impact of Smart City Investment

Source: OSU

Total program and project costs are calculated and presented in **Chapter 3** and used as key inputs to the model. Both program and individual project costs were included. The CGE economic impact analysis method allocates these costs across various sectors such as business consulting, information and communications, and manufacturing (these were the top three sectors for the Smart Columbus Program expenses, accounting for nearly 84% of the budget). These costs were also categorized as labor or capital.

To measure the potential economic impact of the Smart Columbus Program investment, ten scenarios were developed corresponding to the program-level management, the eight individual projects, and one scenario that represents the total impact of the overall Smart Columbus Program. The impact of each scenario was assessed using data collected through the performance measurement process, mainly the program-level survey that was collected to assess performance measurement indicators for the program mobility and opportunity outcomes, although individual project survey results were also used to a lesser extent.

4.3.2. Results

Table 4-1 summarizes the economic impacts of the various Smart Columbus Program projects and the program overall. In terms of projecting the short-run effect, the total capital investment implemented during the project development stage is likely to generate a GMP growth of $147.86 million or a 0.078% increase from that at the base-year level. In addition, the short-run effects of the Smart Columbus Program investment are likely to generate a job increase of 4,220 (representing an employment increase of 0.241%) as compared with the level in 2018.

[34] *The 10 counties in the Columbus Metropolitan Statistical Area (MSA) include Delaware County, Fairfield County, Franklin County, Hocking County, Licking County, Madison County, Morrow County, Perry County, Pickaway County, and Union County.*

Table 10: Computable General Equilibrium Model Outputs

Impact	# Jobs Added[a]	% Change in Jobs	GMP Added ($ millions)	% Change in GMP	Multiplier[b]
Short-Run	4,220	0.241%	$147.86	0.078%	1.90 (avg)
Long-Run	7,039	0.0300%	$671.28	0.538%	N/A

Notes:

a) *The number of jobs was calculated using the aggregate payroll divided by the mean wage level ($54,784.2) of the Columbus MSA in 2018.*

b) *The multiplier, also known as the Keynesian multiplier, reflects the ratio between the indirect value-added and the direct value-added from the capital expenditure of the projects. Hence, it is only applicable in the short-run impact scenario.*

Source: OSU

As mentioned, the long-run projected impacts have more uncertainty, as it is difficult to determine the long-term ongoing productivity impacts of these transportation improvements. However, assuming the reduction of urban traffic congestion and the increased use of urban transit services captured in the Performance Measures Results Report, the impact would eventually lead to a corresponding ratio of changes in productivity and household expenditure on urban transit services. Specifically, this analysis assumed:

- A 13.51% increase in transit productivity (based on the Smart Columbus travel survey)[35]
- A 9.27% increase in household expenditure on urban travel-related service (based on the program survey)

Successful deployment of the Smart Columbus Program projects and utilization of the services is likely to generate a $671.28 million or 0.538% increase in GMP, and 7,039 jobs or an employment increase of 0.3%. An estimated 92% of the effect on GMP and 74% of the effect on employment should be attributed to the productivity improvement in urban transit-related sectors (with the remainder attributable to household expenditures).

Overall, the multiplier of the Smart Columbus Program investment was found to range between 1.71 and 2.09, with an average rate of 1.9, which suggests that each dollar invested in the Smart Columbus Program is associated with an increase of between $1.71 and $2.09 in value added to the local economy.

4.3.3. Conclusions

The analysis shows that Smart Columbus Program projects can potentially generate both short-run and long-run impacts on the local economy. The short-run impact was generated through the investment in factor inputs of related sectors, such as business, information and communication during its implementation stage. The long-run impact was primarily achieved through the changes in productivity of urban transportation sectors and the demand for mobility services. Whether these long-run project impacts are likely to be achieved is dependent on widespread adoption of the projects. This is driven by the type and scale of the project, and the public support for and awareness of the solution.

The economic impact analysis has limitations, some of which may be further developed in the future. For example, the framework was static, not accounting for dynamic effects such as capital accumulation, depreciation, and spatial spillover, as well as uncertainties such as the negative shocks from COVID-19 affecting the projects' results during the demonstration period. The pandemic occurred at the start of the

35 *The change was calculated using the traveler's response of congestion in the two time periods.*

demonstration period for many projects, and the complexities of accounting for this in the analysis were outside the scope and effort planned for the analysis.

OSU's analysis is intended to provide a useful analytical framework for the economic impact assessment of smart city investment. It also provides insights for city planners to better understand the economic benefits of smart city initiatives, which may facilitate better future investment decision-making both in Columbus and other cities. OSU will publish its results in greater detail separate from this report.

4.4. ACCESSIBILITY IMPACT

OSU also performed a space-time accessibility[36] analysis on the reachability of various resources, activities and opportunities given a specific time budget. The analysis focused on the locations of key travel origins, such as home and work, the geographic distribution of opportunities (specifically, jobs and medical offices), and the ability of the transportation systems to facilitate movement among these locations. The space-time accessibility analysis highlights the physical limitations on *potential* mobility afforded by the transportation system in the study area (rather than on *actual* trips taken), based on:

- Vehicle movement speeds afforded by the street network and its attributes
- Public transit routes and schedules
- Sidewalk network for walking and public transit access
- Location and availability of docked bikeshare stations at the time of travel
- Locations of dockless micromobility vehicles (scooters) at the time of travel

The analysis focused on the Pivot app and SMH, which was expected to expand accessibility in the transportation system by facilitating multimodal trip planning and mode choice. Multimodal trips can provide better space-time access than single mode trips by extending the capabilities of any single mode, such as bike-share or micromobility mitigating the first mile/last mile problem in public transit. The theory explored in this analysis is that the accessibility area reachable when taking trips using only the bus and walking is less than trips where a traveler can plan trips using these modes plus additional modes including bicycles and scooters.

The analysis methodology, assumptions, and findings are summarized below, additional detail is provided in **Appendix E**.

4.4.1. Methodology

The space-time accessibility via single-mode travel (a baseline condition available prior to the Pivot app) was compared with that via multimodal trips that can be discovered via the Pivot app (treatment condition). Then, these regions were overlayed with georeferenced employer and health care provider data to compare the differential access to these key community resources.

OSU's research design is as follows:

1. Designate a travel origin and travel time budget
2. Compute the space-time accessibility region corresponding to walk and bus – this represents single mode trip planning that was readily available prior to the Smart Columbus Program

[36] *Miller H.J., (2017) "Time geography and space-time prism," in D. Richardson, N. Castree, M. F. Goodchild, A. Kobayashi, W. Liu and R. A. Marston (eds.) International Encyclopedia of Geography, Wiley, DOI: 10.1002/9781118786352.wbieg0431.*

3. Compute the corresponding space-time accessibility regions corresponding to multimodal trips afforded by the Pivot app
4. Overlay these regions with georeferenced business and health care provider data
5. Compare the two areas to determine how many additional locations can be reached with Smart Columbus Projects. That is, examine the extent of the space-time accessibility region (area that can be reached within a set time range) to the mapping of the business and health care provider locations

4.4.1.1. ASSUMPTIONS

A specific origin location needed to be chosen as a representative location for determining the space-time accessibility region. Given that many of the smart city projects were centered in Linden, the Linden Transit Center (an SMH location) was selected as the representative location. A 30-minute representative time budget was chosen for travel. Thirty minutes is the average one-way commute time in the U.S.[37]

4.4.1.2. EMPLOYERS AND HEALTH CARE PROVIDER LOCATIONS

The map in **Figure 4-10** shows job locations in central Ohio. In addition to total job count, the study examined locations of low-skill jobs (requiring less than high school, high school or equivalent) and locations of high-skill jobs (requiring some college or associate degree, bachelor's degree, or advanced degree). The jobs count data is from the 2018 Longitudinal Employer-Household Dynamics (LEHD) survey by the U.S. Census Bureau.[38]

The map on the right in **Figure 4-11** shows the locations for all health care businesses. The analysis also examined physician's offices separately from other medical facilities.

[37] *30 minutes is sometimes referred to as Marchetti's travel time constant; see Schafer and Victor 2020*

[38] *https://lehd.ces.census.gov/data/*

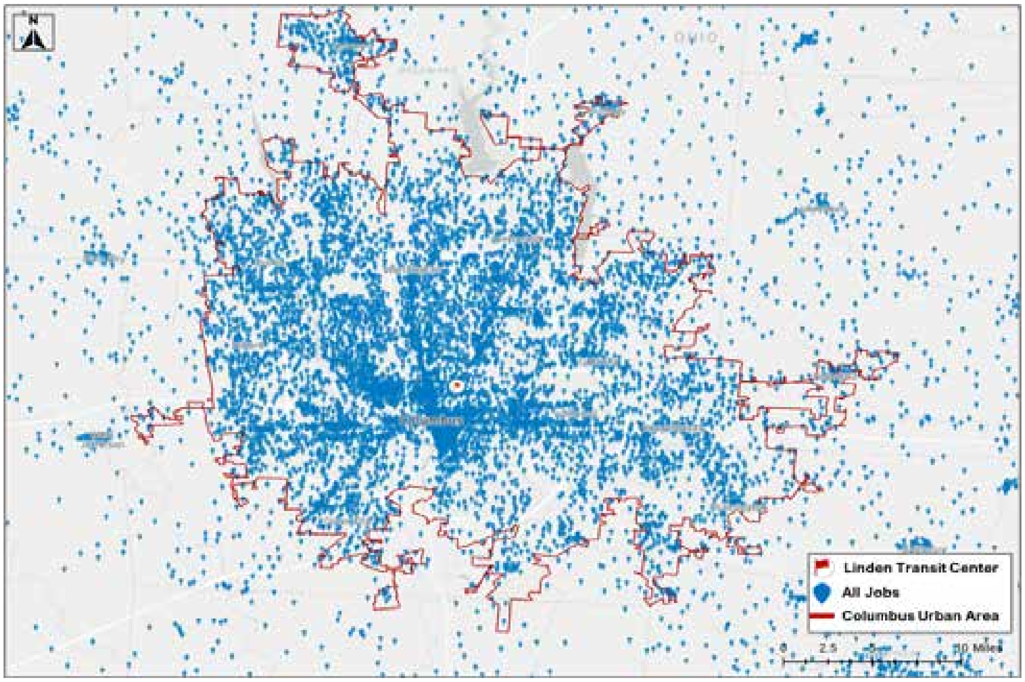


Figure 4-10. Job Locations

Source: OSU

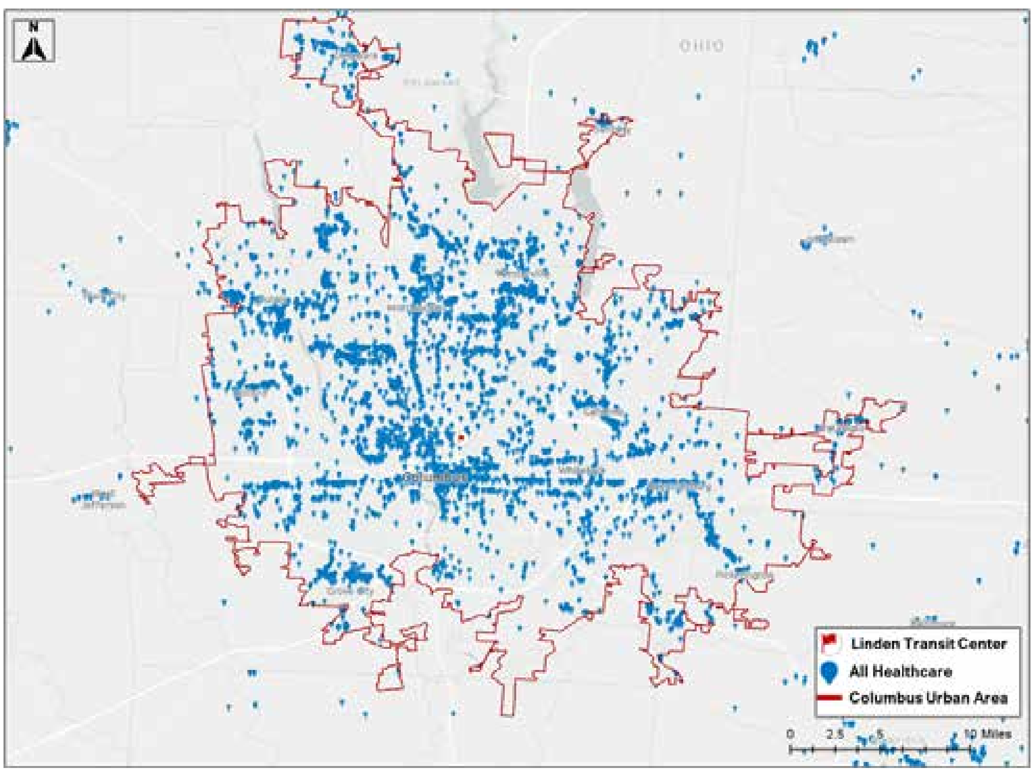


Figure 4-11. Health Care Locations

Source: OSU

4.4.1.3. COMPUTING THE SPATIAL ACCESSIBILITY REGION

The spatial accessibility region was determined using a given travel origin and time budget, and then calculating all possible paths through the multimodal transportation network starting at the travel location, extending outward until the time budget is exhausted

The range of travel modes encompassed by the Smart Columbus projects (Pivot app and SMH most directly) included: walking, CoGo bikeshare, COTA, Campus Area Bus Service (CABS), Yellow Cab, Lyft, Uber, Bird and Lime scooters. The accessibility regions were computed using a tool called OpenTripPlanner (OTP)[39]. OTP is an open-source web application that provides routing and analysis services for multimodal networks. Since the accessibility calculations are based on the detailed bus schedules, Wednesday, February 3, 2021 was chosen as a representative day. Three representative trip origin times were designated: 9am (representing morning peak travel time), 1pm (representing off-peak travel time), and 6pm (representing evening peak travel time). **Figure 4-12** through **Figure 4-14** show the 30-minute accessibility regions pre-treatment using just transit and walking (in purple), and post-treatment with the additional modes available through Pivot (in green).

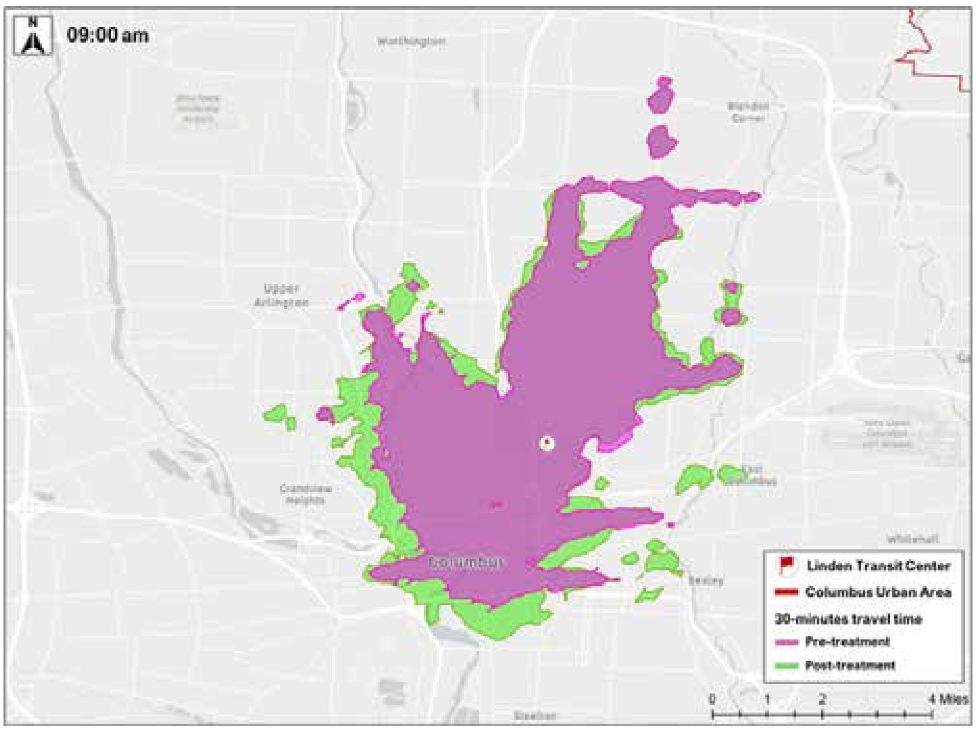


Figure 4-12: Pre/post Accessibility Change (9am)

Source: OSU

[39] http://www.opentripplanner.org/

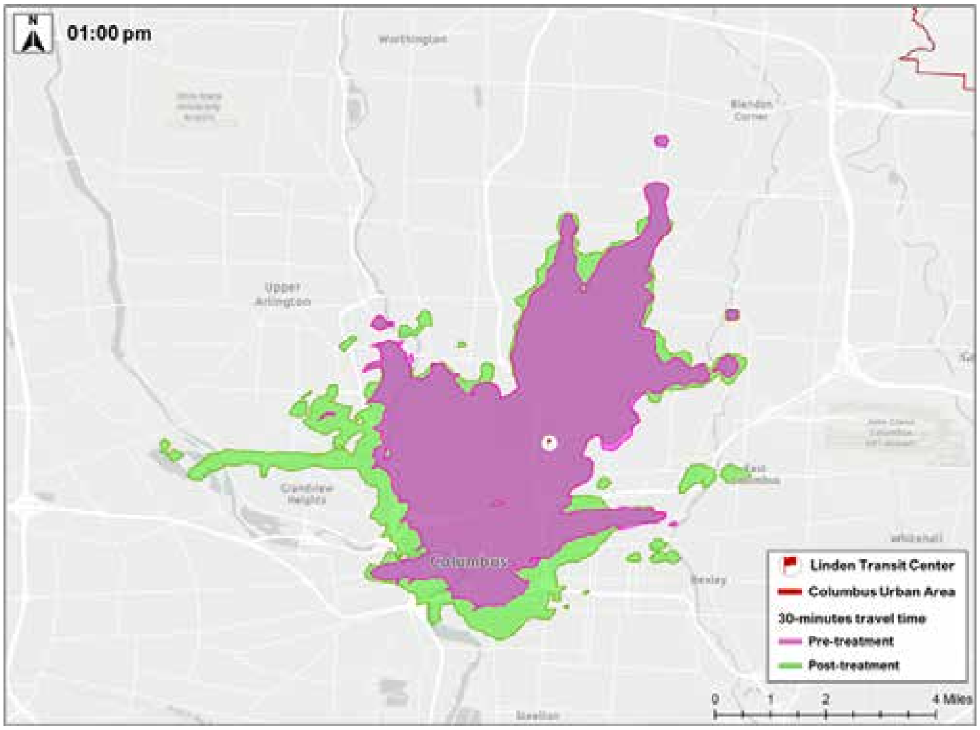


Figure 4-13: Pre/post Accessibility Change (1pm)

Source: OSU

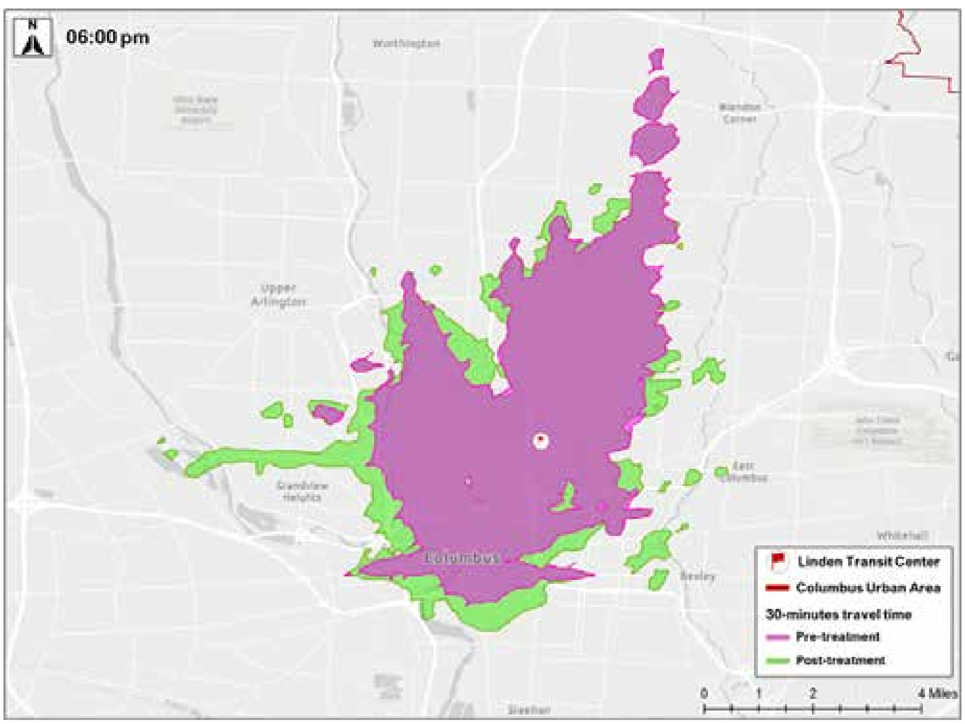


Figure 4-14: Pre/post Accessibility Change (6pm)

Source: OSU

As the figures show, compared to the pre-treatment area, the green post-treatment accessibility area covers a greater geographic extent. The general patterns of the pre/post accessibility areas are similar at all times of day, however there are minor variations due to frequency of the bus service and exact arrival time of buses at particular stops. Accessibility is somewhat greater for peak hours (9am, 6pm) compared to off peak (1pm), due to the higher frequency of bus service at these times. Note that this analysis does not account for the impacts of traffic and bus delays, which would tend to have an adverse effect on accessibility.

4.4.2. Results

As noted above, the access to multiple modes of transportation provided by the multimodal trip-planning capabilities of the Pivot app resulted in expansion of the accessibility areas for all time periods relative to the single-mode trip-planning options that existed previously. The expansion of the accessibility areas is understandably accompanied by access to a greater number of job and health care locations. This is evident in **Figure 4-15**, which show the total number of jobs accessible post-treatment (all modes) compared with those accessible pre-treatment.

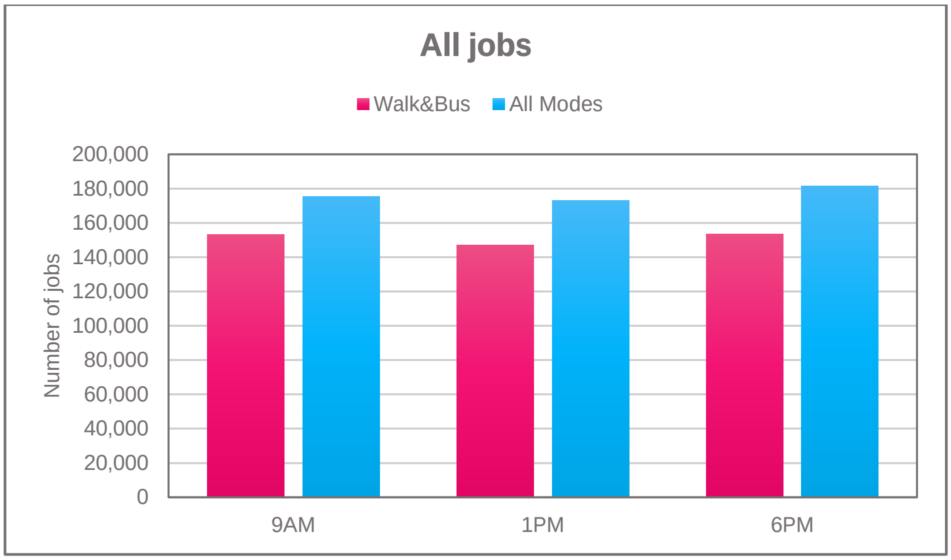
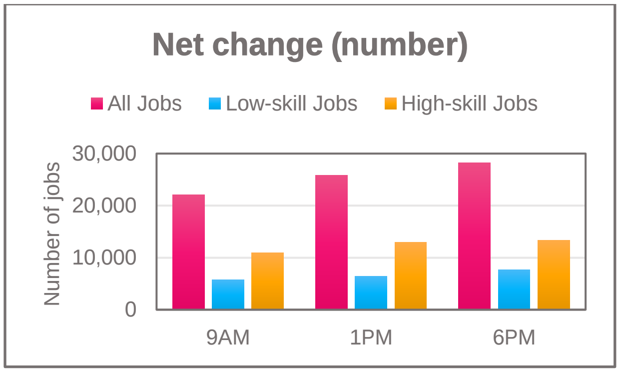


Figure 4-15: Jobs Accessible within 30 Minutes

Note: red shows pre-treatment, blue shows post-treatment
Source: OSU

The degree of the change in accessibility is more apparent when expressed as a net change, as shown in **Figure 4-12**. This figure also breaks out the accessibility by time period and job type. The increase in accessible jobs ranged from approximately 12.6% to 21.6% depending on time period and skill class. The 6pm time period experienced the greatest gains overall with a gain of 28,244 jobs in any class (18.4%). The 9am time period experienced the fewest gains at 22,095 jobs in any class (14.4% increase). Although the absolute change for high-skill jobs was greater, low-skill jobs experienced a greater proportional change due to the lower total number of low-skill jobs in the area.



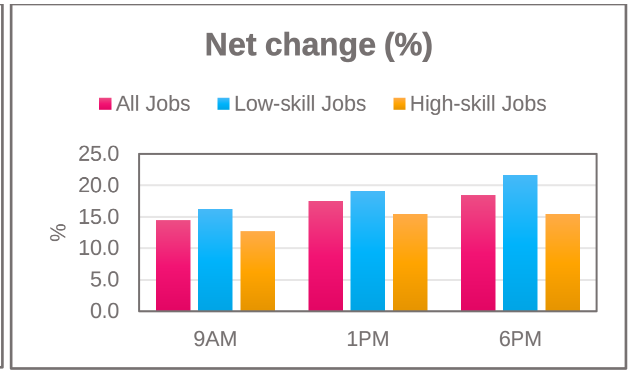


Figure 4-16. Net Change in Jobs Accessible within 30 Minutes

Source: OSU

The expansion of the accessibility areas also resulted in increased access to health care services, as shown in **Figure 4-17**. **Figure 4-17** shows the number of health care service businesses accessible post-treatment compared with those accessible pre-treatment. Figure 4-18 shows the same but for physician's offices only. The number of accessible services increased in both cases for all time periods.

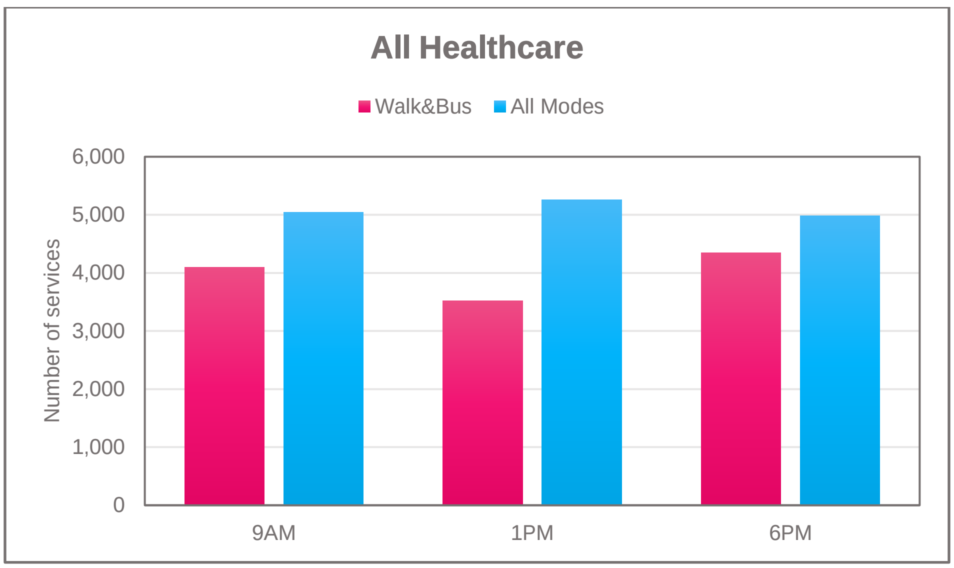


Figure 4-17: Health Care Accessible within 30 Minutes

Note: red shows pre-treatment, blue shows post-treatment
Source: OSU

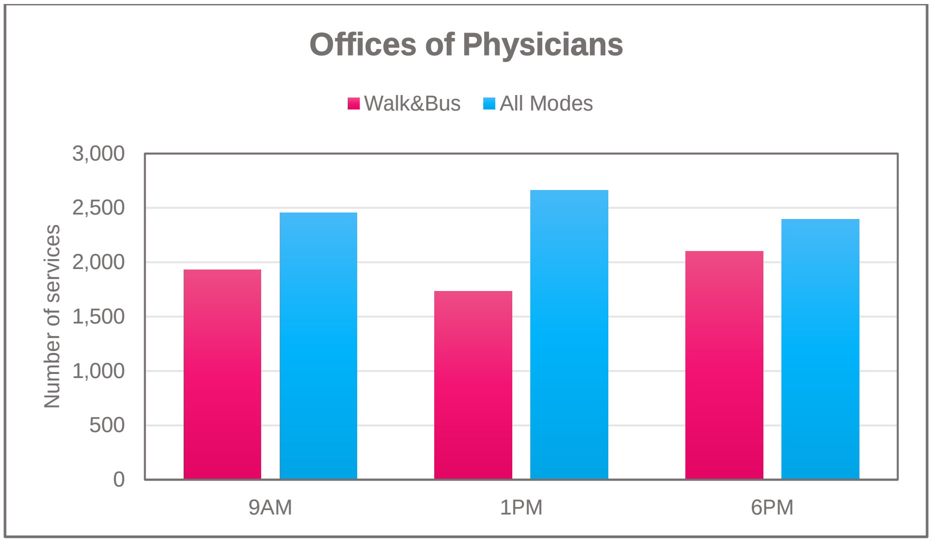


Figure 4-18. Physician's Offices Acessible within 30 Minutes

Source: OSU

Figure 4-19 shows the change in accessibility in net terms, providing additional detail by time of day and facility type. The increase in accessible health care services ranged from approximately 14.1% to 49.3% depending on time period. The 1pm time period experienced the greatest gains overall with a gain of over 1,730 facilities of any type. The 6pm time period experienced the fewest gains at just over 630 facilities of any type.

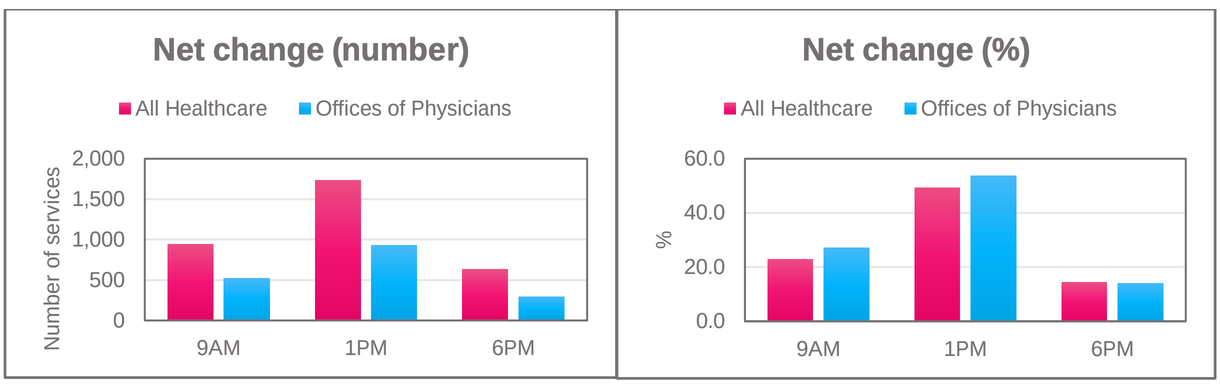


Figure 4-19: Net Change in Health Care Services Accessible within 30 Minutes

Source: OSU

4.4.3. Conclusions

One of the stated goals of the Smart Columbus Program was to encourage travelers to use multimodal transportation. The program took a multi-pronged approach to this objective, including provisioning of services (e.g., CEAV), providing connectivity between services (e.g., SMH), and providing information about services (e.g., MMTPA). This analysis considered the latter, or specifically how the introduction of the Smart Columbus projects (especially Pivot, the multimodal trip planning application, and SMH) would affect the ability of a hypothetical traveler departing from Linden to access jobs and health care services at several times throughout the day constrained by a travel time budget of 30 minutes. The accessibility area reachable in this time budget was computed for the pre-treatment case where the traveler could plan trips using only the bus and walking, as well as the post-treatment case where the traveler could plan trips using these modes plus several rented micromobility options including bicycles and scooters. The number of jobs and health care services in the accessibility area were counted for each case, and the difference between the two cases represents the hypothetical accessibility change that resulted from the introduction of the Smart Columbus projects.

The analysis revealed that the multimodal trip planning capability provided by the Smart Columbus projects resulted in an expansion of the 30-minute accessibility area reachable by a hypothetical traveler departing the Linden Transit Center. As a result of the expansion, the traveler would be able to reach at least 20,000 additional jobs and 3,000 additional health care services than they would using the trip planning tools that existed prior to the introduction of the projects. The increase in accessibility was even greater for certain classes of jobs and services and at certain times of day.

It is important to note that this analysis is primarily focused on the impact of improved access to information, specifically trip planning information afforded by the Smart Columbus projects (the Pivot application and SMH most directly), rather than on access to multimodal transportation services themselves. All of the transportation services included in the analysis exist independently of Smart Columbus, and the allocation of these services is also independent of Smart Columbus except for the additional CoGo stations introduced in conjunction with the SMH facilities. While it is theoretically possible for a traveler to achieve the accessibility gains observed in the analysis by manually integrating trip plans for various services, this would be impractical for most travelers due to the time cost involved and the complexity of integrating the various sources of information. **Therefore, it is the *information* provided by the projects that produces the increase in accessibility rather than the existence of the transportation services themselves.**

For a person living near the Linden Transit Center, this improvement would represent a very real change in opportunity. It can be assumed that the projects have similar effects throughout the region, depending on the availability of micromobility services. It is also important to note that in addition to increasing access to jobs and health care, Smart Columbus projects would similarly increase access to shopping, education, recreation and other opportunities.

4.5. HOUSING MARKET IMPACT

The bundle of improvements provided by SMHs can work to enhance transit functionality via informed trip planning, connect residents to digital services via public Wi-Fi, and provide a reliable location for micromobility options. These can improve the accessibility of areas served by SMHs, especially for residents reliant on public transportation. Given that most of these benefits accrue to those living close to or interacting with the SMHs, there is the potential for SMH improvements to affect nearby property markets. Enhanced mobility is needed to give disadvantaged populations better access to jobs and services, but it is also desirable, making SMH-treated neighborhoods relatively more attractive to live in. Neighborhood improvements can also act as a signal for future investments by private and public actors. This may result in increased purchases and increases in housing prices as buyers expect future price appreciation in treated neighborhoods. SMH-adjacent neighborhoods were evaluated to determine if they display new housing market activity relative to similar neighborhoods. This can indicate whether SMHs act as a trigger for changes that affect the economic and demographic composition, and therefore the beneficiaries, of nearby neighborhoods. While not directly related to the mobility or customer service outcomes explored in the PfMP, these results provide context for how neighborhoods may evolve in the future. A sizeable effect of SMHs on short-run market activity was found that implies a 33.5% increase in sales likelihood for residential parcels. However, no evidence of any appreciation or depreciation of housing prices was found due to SMHs.

It is difficult to identify how these factors are playing out in property markets due to the short timeframe after SMH installation. Delays and disruptions resulting from COVID-19 imply a post-launch period of less than a year, meaning that residents, renters, homebuyers, and landlords are likely still familiarizing themselves with the new services and their associated effects on accessibility. Future work will explore the robustness of these findings and examine longer-run trajectories in treated neighborhoods.

The methodology and findings of this analysis are summarized below, with details available in **Appendix E**.

4.5.1. Methodology

Two housing market outcomes were the focus in this report: sales activity and housing prices. The first test was whether residential parcels in SMH adjacent neighborhoods are more likely to be sold compared to similar neighborhoods. Secondly, it was explored whether SMH benefits have capitalized into neighborhood housing prices. Increased market activity in treated neighborhoods suggests that home buyers and sellers are adjusting to the new mobility services and the associated shifting of neighborhood expectations. Higher housing prices would indicate that buyers are bidding higher to live nearby the enhanced amenities. Over time, increased activity might be expected to result in higher prices but need not immediately occur.

To isolate the effects of SMHs, counterfactual locations (neighborhoods without SMHs) needed to be identified to compare with SMH-treated neighborhoods.

OSU developed a sample of transit station-centered counter-factual neighborhoods similar to those with SMHs in surrounding land use, demographic characteristics, and transit ridership. The analysis uses a final sample of five control neighborhoods and three treatment[40] neighborhoods. While SMHs were not brought fully online until late summer 2020, announcements of the locations and construction began and were complete by winter 2020.

[40] *"Treatment" is conceptualized as being a residential parcel (or housing transaction) in a transit-centered neighborhood augmented by a SMH after 2020.*

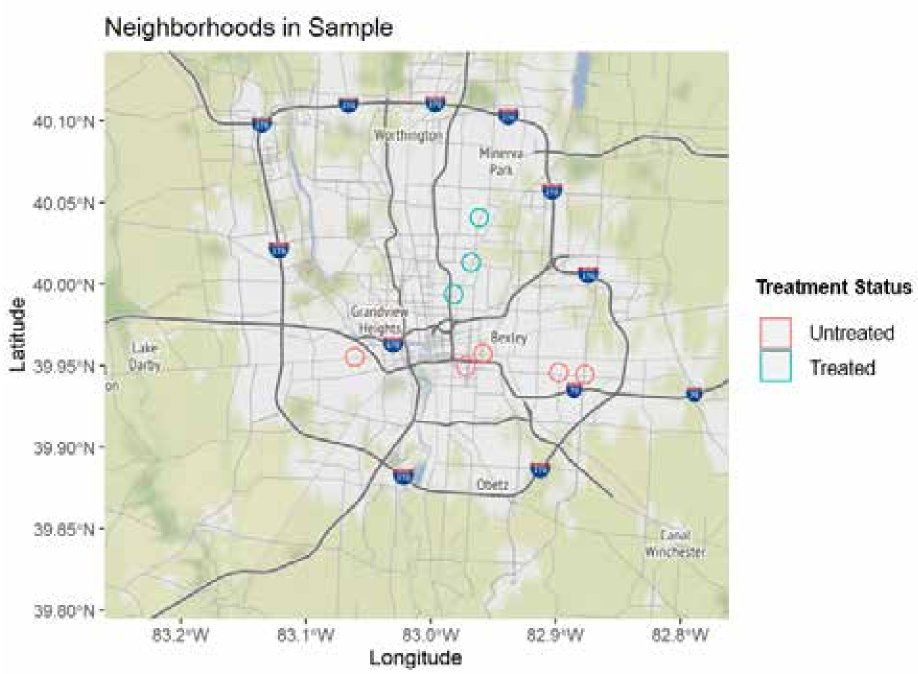


Figure 4-20: Smart Mobility Hub Locations Used in the Housing Market Impact Analysis

Source: OSU

A difference-in-differences (DiD) strategy was used to isolate the effects of SMH investments on the two outcomes of interest. See **Chapter 2** of the PfMP for a general description of the DiD methodology. The key assumption underlying this approach is that any post-treatment change in the outcomes of interest in treated neighborhoods relative to control neighborhoods can be attributed to SMHs, after controlling for parcel-level characteristics, year averages, and neighborhood averages.

The analysis separately estimates the following models for the two outcomes (transactions and housing prices). For residential market activity, the sample is a balanced panel of residential parcels from 2016 to March 2021.

4.5.2. Results

The analysis results suggest a sizeable increase in sales activity in SMH-adjacent neighborhoods, but no evidence of any capitalization of these SMHs into housing prices. It finds that SMH installation increased the probability of a parcel selling in treated neighborhoods by 2.03%. Given the sample average sale probability of 6.06%, this corresponds to a 33.5% increase in the likelihood of sale due to SMH installation.

Alternatively, the results of the hedonic model provide no evidence of any price appreciation, though these estimates are imprecise in part due to the small post-treatment sample size.

4.5.2.1. ADDITIONAL ANALYSIS

Recent public investments into treated neighborhoods, including the introduction of a new bus rapid transit line (CMAX), may interfere with the assumptions of the DiD model. While these investments predate treatment, they may change neighborhoods in ways that create differential trends between neighborhoods similar in the baseline period (e.g., 2016). A similar analysis using a sample of parcels along the CMAX corridor was therefore run to check the analysis' findings. While treated neighborhoods are defined similarly, control parcels (untreated parcels) are those within a half mile of the CMAX Corridor, but not within a half mile of an SMH. In this case, all properties in the sample are exposed to CMAX improvements, as well as other neighborhood investments or initiatives.

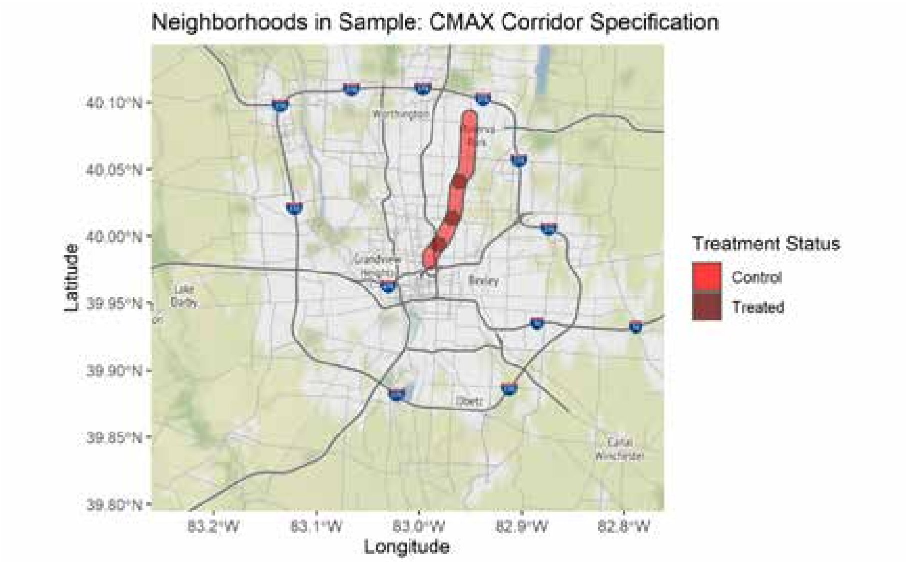


Figure 4-21: Illustration of SMH (Treated) and Counterfactual (Control) Locations in CMAX Robustness Check

Source: OSU

For market activity, similar results using the CMAX corridor sample were seen, although coefficients (impacts of treatment) are slightly smaller in magnitude. In this CMAX corridor analysis, SMH installation has increased the probability of a parcel selling in treated neighborhoods by 1.50%, corresponding to a 25% increase in the likelihood of sale. Consistency across the two different approaches suggests that SMHs have increased market activity in nearby neighborhoods. In addition, the CMAX-only analysis suggests a sizeable capitalization of SMHs into housing prices of 17%. Taken together with the results from the previous specification, there is some evidence of moderate house price appreciation resulting from SMH investments in treated neighborhoods, though this is inconclusive.

This increase in market activity warrants future research examining how the SMH-treated neighborhoods evolve over time. Increased activity can be an indicator of stimulated investment into the neighborhood but can also be a leading indicator of neighborhood change and gentrification, changing the composition of who benefits from the policy. Neighborhoods with SMHs are poorer, with high percentages of renters and minority residents. While new investment in housing and property can be a boon to homeowners, the benefits of the increased value of local housing may not extend to poorer residents who rent.

A major confounding factor is the COTA's Bus Rapid Transit (BRT) Service (CMAX), introduced to SMH adjacent neighborhoods, but not to those control neighborhoods along other frequent COTA lines. While removing potential neighborhoods close to SMH neighborhoods removes the potential for spillovers (e.g., treatment affects the control neighborhoods), this limits the ability to separate the SMH effect from the impact of CMAX transit service. Another key limitation of this study is the lack of data on residential rents. These may be more responsive to the amenity benefits of the SMHs versus the long-term expectations of homeowners and investors. Future research will focus on housing improvements, neighborhood composition, and the types of buyers contributing to this increase in market activity.

4.5.3. Conclusion

Currently, there is potential for the SMHs to increase demand for housing in the Linden area with a corresponding rise in housing prices. If housing prices increase, it would benefit homeowners, however, most current residents are renters who may be priced out of the area if rents increase. Without monitoring such potential impacts, the disadvantaged population the SMH was intended to help may be displaced and unable to benefit from the SMH in the long run. OSU will continue to study these impacts after the Smart Columbus Program concludes.

4.6. SUMMARY

Overall, the Smart Columbus Program was successful in achieving 22 out of 29 objectives specified for the program in the PfMP.[41] None of the objectives were unsuccessful; rather, seven evaluations produced inconclusive results due to small sample size (such as only seven trips booked using Pivot at SMHs) or COVID-19 impacts on travel behavior and traffic conditions (such as dramatically reduced demand for parking). Results by program-level outcome and by project are shown in **Figure 4-22**.

In addition to achieving the designated objectives, the performance measurement and evaluation process produced valuable insights that can be applied in scaling up use of these technologies and sharing lessons learned to facilitate smart city initiatives throughout Ohio and nationwide. These insights include interest in and comfort with various technologies, public outreach and training needs for scale up, and areas for improvement (see **Figure 4-23**).

[41] *https://d2rfd3nxvhnf29.cloudfront.net/2021-04/SCC-C-PfMP-Update-v3%203.30.21.pdf*

OUTCOMES →	SAFETY	MOBILITY	OPPORTUNITY	ENVIRONMENT	AGENCY EFFICIENCY	CUSTOMER SATISFACTION
CONTRIBUTING PROJECTS	→ CVE	→ SMART COLUMBUS PROGRAM → MMTPA → SMH → MAPCD → PTA → CEAV	→ SMART COLUMBUS PROGRAM → MMTPA → MAPCD → PTA → CEAV	→ SMART COLUMBUS PROGRAM *Projects assessed as a group:* → CVE → MMTPA → EPM	→ SCOS → MAPCD *MAPCD project assessed as "inconclusive; because participants were not existing paratransit users*	→ SCOS → MMTPA → SMH → PTA → EPM → CEAV
PROGRAM FINDINGS	*Not applicable; only CVE project evaluated for Safety benefits*	Improved ease of transferring modes Modest reduction in traffic delays and traffic volume observed during peak weekday hours	Significantly easier trip planning post-Smart Columbus Accessibility area expanded by 30 minutes from Linden Transit Center Established access to 20,000 more jobs and 3,000 more health care services	Inconclusive due to small sample sizes and impact of COVID-19 pandemic on travel behavior Projects assessed as a group have potential to reduce greenhouse gas emissions post-pandemic	*Not applicable; only SCOS and MAPCD projects evaluated for Agency Efficiency benefits*	*Not applicable; Customer Satisfaction evaluated only at project level*
HIGHLIGHTS OF PROJECT OBJECTIVES ACHIEVED	CVE: › Emergency response times (average speed and travel time) improved by average of 1.64% when signal preemption granted; improvement of up to 5.2% noted › Vehicle speeds reduced by average of 2.3 mph when approaching red light › School zone speed limit compliance improved from 18% to 56%	EPM: Significant improvement in mean response time taken to find parking for leisure activities MAPCD: Shifted 82 trips from the personal vehicles of caregivers to public transit CEAV: 265 walkups at the Rosewind stop	MMTPA: Significant increase in access to health care and entertainment MAPCD: Participants reported sense of greater independence PTA: Percentage of participants who did not take NEMT trips decreased from 44% to 19% CEAV: Over 130,000 meals transported to neighbors in Linden	PAUL G. ALLEN FAMILY FOUNDATION GRANT: › 3,458 EVs purchased › 914 charging ports installed › 18.6 million people educated about Smart Columbus Program	SCOS: › Over 800 agency-related datasets › 222,685 downloads › 67,156 queries › 59% of users rated their experience of finding intended data as good to very good › Agency users cited improved data-sharing ability › Over 60% of users said experience accessing and using data was good to very good	SCOS: Over 70% rated various functions good or very good MMTPA: Over 97% found Pivot easy or very easy to use PTA and CEAV: 90% were satisfied, very satisfied or extremely satisfied EPM: Over 30,000 app downloads; 82% users say they will use new app features

Figure 4-22: Overview of Performance Measures Results

Source: City of Columbus

	SCOS	CVE	MMTPA	MAPCD
Key Highlights	• Highly utilized • Efficient and effective data discoverability and sharing	• Improved emergency response times, helped avoid crashes from running red-lights, and reduced speeding in school zones	• Significant improvement in ease of transferring modes and access to healthcare and entertainment	• Successfully improved feeling of independence/ comfort with using public transit • High satisfaction with training provided
Future Potential	• Ingesting more datasets would scale up efficiencies achieved, now that the backbone is in place.	• More widespread use could amplify benefits, including potential greenhouse gas savings (results inconclusive due to sample size)	• Many were somewhat or extremely likely to use Pivot in the future • Varied Pivot awareness levels can inform future targeted marking efforts	• Hesitancy to use new technology or change behavior is an obstacle to scale-up, but study confirmed value and can inform future marketing and training strategy
	PTA	**SMH**	**EPM**	**CEAV**
Key Highlights	• PTA implementation increased utilization of prenatal trips • Improved participant satisfaction over baseline	• Small sample size precluded meaningful analysis	• Small sample size and dramatically reduced parking demand precluded meaningful analysis	• Effective in helping bridge the FM/LM gap for food pantry patrons • High usage and positive feedback from patrons
Future Potential	• Program scale-up has the potential to amplify benefits	• Potential benefits may still be realized with increased usage post-COVID-19 and with improved weather • Marketing campaign may be helpful to encourage usage	• As larger events resume, potential benefits of the EPM may still be realized, including reduced congestion and time to find parking, which in turn could reduce emissions	• Food pantry use case provided first-hand experience to increase comfort with the technology • Can leverage momentum for passenger transport or other use cases post-COVID-19

Figure 4-23: Key Highlights and Future Potential By Project

Source: City of Columbus

OSU's supplemental economic, accessibility and housing market analyses, while outside the PfMP scope, provide valuable insight into current and potential future benefits of the Smart Columbus Program. These are summarized in **Figure 4-24**, which also includes areas for future research.

	Economic Impact	Accessibility Impact	Housing Market Impact
Key Highlights	• Each $1 invested in the Smart Columbus Program is associated with $1.17 to $2.09 in value added to the local economy Projected short-run effect: • **$174.8M (0.07%) GMP growth** • **4,220 more jobs** (0.24% job growth) Projected long-run effect*: • **$671.2M (0.53%) GMP growth** • **7,039 more jobs (0.3% job growth)**	• Multimodal trip planning capability provided by Pivot and SMH resulted in an **expansion of the area that can be accessed within 30 minutes** (hypothetical traveler departing the Linden Transit Center); • Expanded accessibility area enables access to **20,000 additional jobs and 3,000 additional healthcare services** than prior to the Smart Columbus program.	• **33.5% increase in the likelihood of a sale** due to SMH installation • No evidence of price appreciation but may be due to small sample size
Future Potential	• Scaleup of projects may amplify benefits • Results can inform city planners, facilitate better future investment decision-making in Columbus and beyond **92% of the effect on GMP and 74% of the effect on employment should be attributed to the productivity improvement in urban transit-related sectors*	• Further marketing of Pivot's enhanced features would be needed to realize potential benefits through actual trips; • Marketing could be focused on disadvantaged communities to improve access for the most vulnerable populations. • Similar gains may exist in other areas already but also could be amplified by expansion of multimodal services.	• Increased desirability of the area due to improved access may lead to increased housing demand and prices. • Risk of pricing out existing residents (majority are renters) and changing the area's demographics, rather than benefiting the intended disadvantaged population

Figure 4-24: Key Highlights and Future Potential for Supplemental Analyses

Source: City of Columbus

Chapter 5. Conclusions, Lessons Learned and Recommendations

The City of Columbus won the Smart City Challenge (SCC) based on its guiding belief that mobility is the great equalizer of the 21st century. With the $40 million in funds awarded by the United States Department of Transportation (USDOT) and $19 million provided by cost-share partners, the City of Columbus sought to demonstrate how advanced mobility technologies can create more equitable access to transportation, opening doors to jobs, health care, education, and other opportunities that empower residents.

Through this demonstration, the City has piloted a robust portfolio of intelligent transportation systems that were fueled by data, and integrated them into existing City infrastructure. Through this process, Columbus has captured measurable outcomes for how these technologies have improved safety, mobility, opportunity, environment, agency efficiency and customer satisfaction, while also observing positive economic impacts for residents. Projects from this portfolio will be sustained to continue to serve the mobility needs of Columbus residents, and the partnerships and project management methodologies honed throughout the program will benefit the community for years to come.

In deploying these projects, Columbus has also created a technology and program management playbook that will benefit cities throughout the country as they pursue their own smart city journeys. This chapter summarizes the conclusions, lessons learned and recommendations from Columbus' experience.

5.1. CONCLUSIONS

5.1.1. A Unique Opportunity, a Unique Deployment

The SCC inspired and enabled Columbus to deploy the most comprehensive set of mobility technology demonstrations in a four-year, nine-month period of any U.S. city, achieving a powerful set of desired outcomes. The USDOT SCC invited cities to use technology to address 12 vision elements (**Figure 2-7**) that would demonstrate emerging transportation technologies' potential to solve urban challenges experienced in cities nationwide: traffic congestion, crashes, infant mortality, poverty, unemployment, and more. This report concludes that the Smart Columbus Program demonstrated outcomes against the each of the 12 vision elements, as detailed in **Chapter 2, Section 2.4**. In addition, the program demonstrated positive results against the set of six outcomes defined in the City's SCC application (**Figure 1-2**), measuring success on 22 of 29 objectives identified in the Performance Measurement Plan. Finally, with five of the eight projects in the portfolio continuing after the Cooperative Agreement, this unparalleled deployment has created sustainable solutions in Columbus.

5.1.2. Exploration of Emerging Technology Through Real- World Demonstrations

The SCC Program explored emerging mobility technologies through real-world demonstrations, showing how these technologies can achieve beneficial outcomes locally and in cities nationwide. Pioneering deployments of emerging technologies in real-world conditions are described in the following sections.

5.1.2.1. AUTOMATED VEHICLES

The Smart Columbus Program demonstrated and assessed the use of automated vehicles in three deployments for the movement of goods and people:

- The Smart Circuit deployment demonstrated automated vehicle operation in an urbanized area in mixed-use traffic.
- The Linden LEAP (Linden Empowers All People) became the nation's first daily operating public self-driving shuttle in a residential area, demonstrating how an automated shuttle route may be designed as a first mile/last mile (FMLM) connection to public transportation.
- Although unexpected, the Linden LEAP food pantry service solved a specific community use case during the pandemic while demonstrating the use of an automated vehicles (AV) for the movement of goods **(Figure 5-1)**.

Figure 5-1: Linden LEAP Food Pantry Service

Source: City of Columbus

"Man, it was wonderful! Give you a grade on it? Outstanding, A plus. It was really unexpected. It was like right there. Then as I began to come like every week it just became a habit, I just got going every week." -Food Pantry Patron, Survey Response

5.1.2.2. CONNECTED VEHICLES

In demonstrating vehicle-to-vehicle and vehicle-to-infrastructure applications of connected vehicle technology, the Connected Vehicle Environment (CVE) project connected over 1,000 vehicles consisting of emergency vehicles, City fleet vehicles, transit buses and residents, with 85 signalized intersections along four distinct corridors. The project also fostered a collaboration with local automotive shops for the installation and removal (as requested) of the equipment, engaging with these business owners and training their technicians on this emerging technology.

Figure 5-2: CVE Heads-Up Display

Source: City of Columbus

5.1.2.3. ELECTRIC VEHICLES

Beyond the Paul G. Allen Family Foundation grant awarded through the SCC, which had the singular goal to measurably decrease greenhouse gas emissions by electrifying light-duty transportation, all self-driving shuttles that operated within the Connected, Electric, Autonomous Vehicle (CEAV) project were electric. This yielded information on vehicle range and charging infrastructure for fixed-route AV deployments that can benefit the design of future systems. Furthermore, Central Ohio Transit Authority (COTA) installed electric vehicle (EV) charging stations at the Northern Lights Park and Ride Smart Mobility Hub (SMH), thanks to an American Electric Power (AEP) grant.

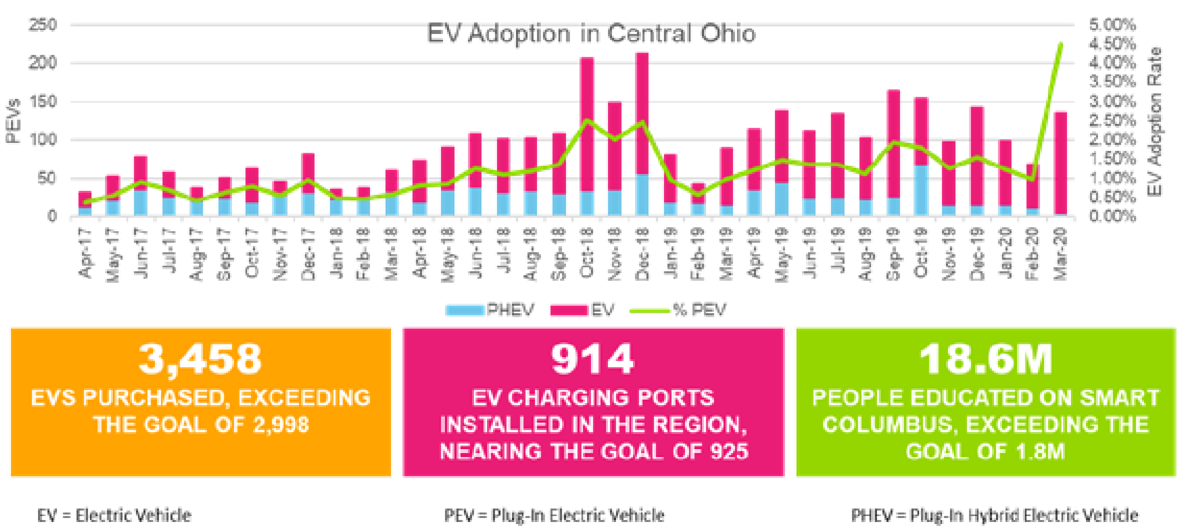


Figure 5-3: Paul G. Allen Family Foundation Grant Outcomes

Source: City of Columbus: https://d2rfd3nxvhnf29.cloudfront.net/2021-03/SCC-PGAFF-FinalReport_07.31.20.pdf

5.1.2.4. SHARED MOBILITY

The Smart Columbus Program created tools that will make it easier for Columbus residents to access and use shared mobility now and into the future. The Pivot app integrated six modes of shared and personal transportation, while SMHs expanded the Linden neighborhood's access to shared bikes and created infrastructure designed to facilitate mode transfer (see **Figure 5-4**). The Mobility Assistance for People with Cognitive Disabilities (MAPCD) project also empowered individuals with cognitive disabilities to transition from rides provided by their caretaker to public transit.

Figure 5-4: Northern Lights Smart Mobility Hub

Source: City of Columbus

5.1.2.5. INTELLIGENT MOBILITY

Sensors integrated into the SMH, Multimodal Trip Planning Application (MMTPA), CVE and Event Parking Management (EPM) projects, when synthesized by the Smart Columbus Operating System (OS), enabled measurable safety, mobility and efficiency outcomes. Pivot, MMTPA's mobile app, uses machine learning to combine external data sources and the user's own trip history to make better recommendations and provide alerts to potential delays during the trip. The OS and EPM project teams worked together to create a predictive algorithm that uses multiple data sources, including transaction and real-time sensor data, to calculate the probability of finding an on-street parking space (see **Figure 5-5)**. This technology has proven useful as downtown commuters may have given up monthly parking arrangements during the COVID-19 pandemic, and will be even more beneficial as parking demand increases post-pandemic.

Figure 5-5: ParkColumbus Parking Predictions

Source: City of Columbus

5.1.3. Implementation Using Innovative Design and Deployment Methodologies

The City implemented its technology programs and projects using innovative design and deployment methodologies. Beyond being notable for deploying a robust array of technologies, the delivery of the program also demonstrated agile methods of technology delivery that included the key elements described below.

5.1.3.1. HUMAN-CENTERED

Stakeholder interviews, focus groups, and end user input informed every technology deployment, with an intended use case in mind. Pivot users were engaged during development through focus groups and beta testing, and the human-centered design is reflected in the stated personal preferences within the Pivot app which informs mode options and route design in the travel plans it recommends. Meanwhile, the Prenatal Trip Assistance (PTA) and MAPCD projects were designed based on the mobility needs of specific groups, respectively creating non-emergency medical transportation for pregnant individuals and empowering people with cognitive disabilities to travel independently via public transit. In the case of MAPCD, the user needs from the trade study, along with results of application testing from The Ohio State University (OSU), created a list of enhancements that were implemented in AbleLink's WayFinder application that was ultimately deployed with the project participants for demonstration.

Figure 5-6: CEAV Working Group Session 2017

Source: City of Columbus

5.1.3.2. REPLICABLE

Establishing governance and using published standards from USDOT where applicable for the projects ensured that technology solutions were designed for replicability, enabling other cities to benefit from the technologies. Another key aspect of replicability is the application of cloud-agnostic and open-source tools. This combination is perhaps best exemplified by the OS, which is a replicable, extensible, and sustainable data management platform designed to serve the needs not only of public agencies, but researchers, entrepreneurs, and the private sector as well. Similarly, MMTPA uses a foundation of open and proven technologies that have already been leveraged by other transit agencies and departments of transportation.

5.1.3.3. COLLABORATIVE

Partners from throughout the community, including COTA, DriveOhio, the Mid-Ohio Regional Planning Commission (MORPC), OSU and the region's private sector helped to advise the development, implementation, and ultimate sustainment of the projects within the portfolio. Resources from numerous key leveraged partners were also used for many of the projects, from Amazon Web Services (AWS) and Battelle providing key support to the operation of the OS to DriveOhio, OSU, The Columbus Partnership and the City all working together to define and deliver the CEAV project.

5.1.4. Deployments Delivered Quantifiable, Purposeful Outcomes

Deployments were not demonstrations of “tech for tech’s sake” but instead delivered quantifiable outcomes that sought to serve the community. While the COVID-19 pandemic presented challenges to implementing the full portfolio as originally envisioned and scoped, deployments of these technologies delivered measurable progress against all of Columbus’ six intended outcomes, with more promise as travel returns to normal when the pandemic ends.

5.1.4.1. SAFETY

The CVE project connected emergency response vehicles with emergency vehicle preemption (to prioritize travel through signalized intersections), and provided these vehicles, as well as City fleet vehicles, transit buses and personal vehicles, with in-vehicle red light violation warning and school zone speed limit notifications. The resulting conclusive safety outcomes included:

- Emergency response times improved 1.3% to 5.2% when signal preemptions were granted.
- Vehicle speeds were reduced at an average of 2.3 miles per hour approaching red lights in the connected vehicle environment.
- Compliance with school zone speed limits improved from 15% to 56%.

5.1.4.2. MOBILITY

Despite significant COVID-19 pandemic impacts on travel and transit, the Smart Columbus Program was able to demonstrate partial or full success of five out of its eight mobility objectives. While the remaining three objectives had inconclusive results due to sample size and COVID-19 impacts, none of the objectives were unsuccessful and all hold promise once travel habits and patterns return to pre-pandemic levels.

- Users of Pivot reported significantly higher scores for ease of transferring modes than those who had not used the app.
- A modest reduction in traffic delays and traffic volume was observed during peak weekday hours.
- PTA participants took nearly 10 times as many non-emergency medical trips – a median of 19 for those receiving enhanced service compared to a median of two for those in the control group.
- The MAPCD project shifted 83 trips from the personal vehicles of caregivers to public transit with an improved feeling of perceived independence.
- In total, nearly 130,000 meals were transported to neighbors in need during the redeployed service of the Linden LEAP.

5.1.4.3. ENVIRONMENT

While greenhouse gas savings calculations were inconclusive on account of small sample size and the impacts of the pandemic, the Smart Columbus Program reduced transportation’s negative impacts on the environment by implementing advanced technologies and policies that support a more sustainable transportation system. Pivot encouraged and will continue to enable travelers to shift away from single occupancy vehicles. Additionally, CVE Signal Priority (especially freight signal preemption) provided opportunity to reduce truck-related emissions and save fuel, and EPM was designed to reduce parking congestion by making it easier to find and take a direct route to parking.

5.1.4.4. OPPORTUNITY

Providing improved access to transportation options for Columbus residents was of vital importance to the Smart Columbus Program. The program sought to increase underserved communities' access to a wide variety of services through transportation solutions focused on improved access to places of employment, education, health care, and other services, and to address barriers that travelers face with existing transportation systems. All five objectives for this intended outcome were achieved with full or partial success, with measurable outcomes including:

- Survey respondents reported a significant increase in access to health care (baseline: 4.33, treatment: 3.27 on a 7-point scale where lower is easier) and entertainment (baseline 3.36, treatment: 2.63) after implementation of the Pivot app, and a marginal increase in ease of getting to work (baseline: 3.9, treatment: 2.93)
- MAPCD participants achieved a feeling improved independence as the WayFinder app gave them the support needed to travel on fixed route bus service alone, without having to rely on a ride from caregivers, friends or family.
- The number of participants in the PTA study who did not take nonemergency medical transportation trips decreased from 44% in the usual care group, to 19% of participants in the intervention group.
- The CEAV shuttles helped mitigate FMLM transportation obstacles by bringing food pantry boxes to the Rosewind Community Center, making it easier for many food-insecure residents to access the food they rely on. This was especially important during the pandemic when food pantry demand increased and there was hesitancy or inability to ride public transportation or get rides from friends and family without risking COVID-19 exposure.

Beyond the objectives in the Performance Measurement Plan, OSU also evaluated the opportunity afforded by the transportation system through the application of Smart Columbus projects. The accessibility analysis evaluated the improvement in potential mobility provided by the application of Smart Columbus projects to access employment and community services. It used the Linden Transit Center as a representative starting location, and examined public transit routes and schedules, sidewalk networks, the location and availability of docked and dockless micromobility options, and other information to compute the area that could be reached within a set travel time (30 or 60 minutes) both with and without the Smart Columbus project improvements. The analysis then computed the number of job and health care locations that could be reached within the set travel time with and without the improvements:

- The accessibility area (defined as the area a traveler could reach within 30 minutes) expanded regardless of the time of day assessed (9 a.m., 1 p.m. or 6 p.m.), as shown in **Figure 5-7**.
- As a result of the expansion, travelers would be able to reach at least 20,000 additional jobs and 3,000 additional health care services than they would using the trip planning tools that existed prior to the introduction of the Smart Columbus projects. The increase in accessibility was even greater for certain classes of jobs and services and at certain times of day.

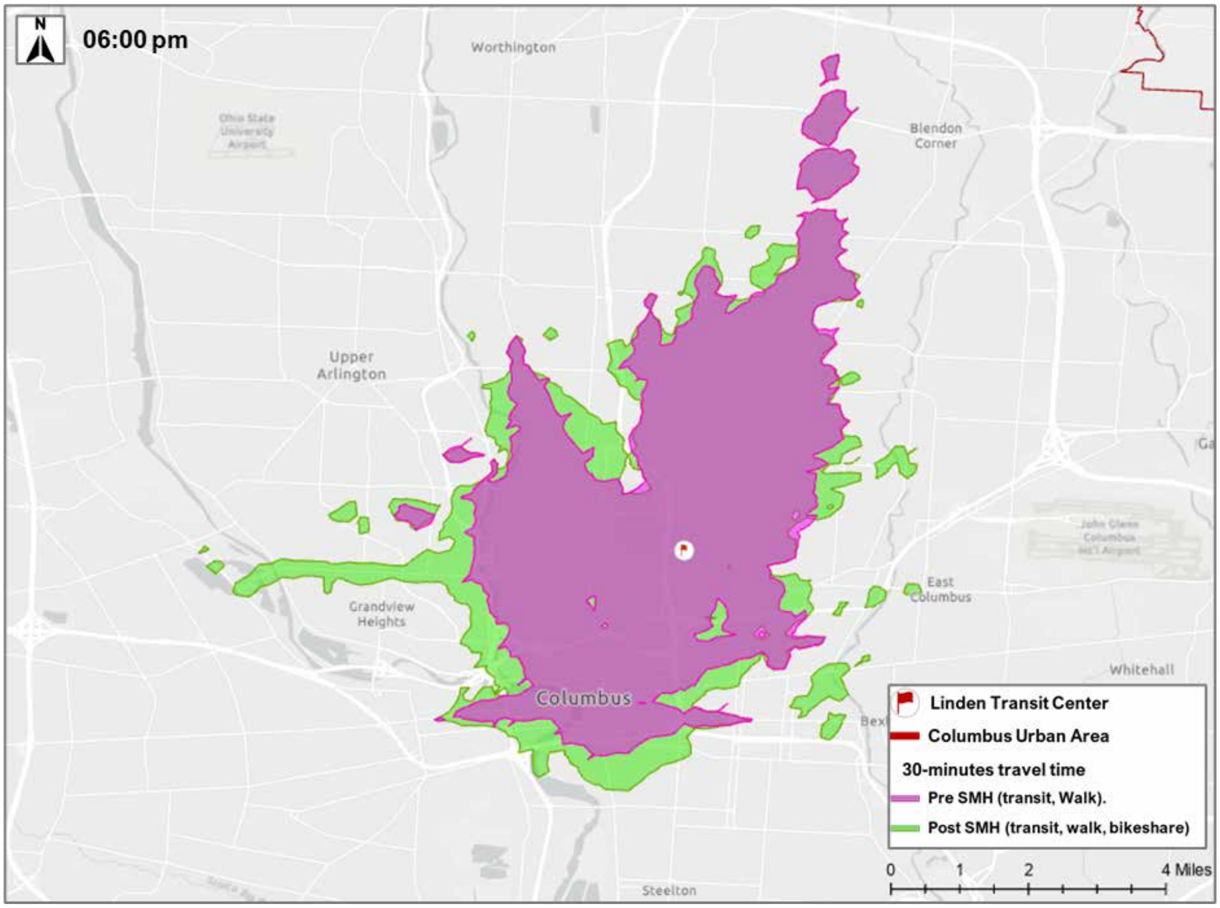


Figure 5-7. OSU Accessibility Analysis

Source: OSU

These accessibility improvements can provide benefits to those living close to or interacting with the SMHs. Specifically, OSU's housing assessment analyzed SMH-adjacent neighborhoods to determine if they displayed new housing market activity relative to similar neighborhoods. The results indicated potential for the SMHs to increase demand for housing in the Linden area with a corresponding rise in housing prices. The housing analysis results provide context for how neighborhoods may evolve in the future:

- A sizeable effect of SMHs on short-run market activity was found that implies a 33.5% increase in sales likelihood for residential parcels.
- However, evidence was inconclusive regarding any change in housing prices due to proximity to SMHs.

5.1.4.5. AGENCY EFFICIENCY

The Smart Columbus Program improved the ability of government, transportation, and community agencies to provide services to residents through advanced technologies. It also enabled easier access to real-time data, streamlined internal processes to improve communications and information sharing, and made internal agency operations more efficient. The Smart Columbus Program achieved four out of five of its agency objectives, and one was inconclusive.

- There were a total of 806 agency-related datasets, with 8% (64) program-related and 92% (742) external to the Smart Columbus Program. Likewise, of the 209 visualizations that were created, a majority were for non-program Agency users (52% vs. 48% for program).
- Over 60% of users said experience accessing and using data was "good to very good". Preview mode was a highly ranked feature.
- For a total of 19 datasets ingested from COTA, 841 downloads and more than 3,500 queries were performed by the OS external users. A constant upward trend of queries and downloads of the datasets was observed, indicating that the OS customers find value with the datasets published.

5.1.4.6. CUSTOMER SATISFACTION

The Smart Columbus Program aimed to provide services that are useful, easy to use, and embraced by the community. The Smart Columbus Program improved the user experience for residents planning for, paying for, and using transportation services through the integrated exchange of data and use of advanced technologies to help travelers reach their destinations. Customer satisfaction was high across all contributing projects that produced measurable results:

- **OS –** Over 70% responded good or very good for various functions
- **MMTPA –** Over 97% found Pivot easy or very easy to use
- **PTA and CEAV –** 90% were satisfied, very satisfied, or extremely satisfied

Collectively, these demonstrations performed as intended: they tested the technology, validated the value propositions of technology features, provided insights into how to maximize the technology benefits, and increased awareness of the technology in the community. These demonstrations also built a foundation for scaling similar and related technologies in the future.

5.1.5. Establishment of Long-Term Projects

The projects established through the SCC will continue to serve the community past the program's term. For each project within the program portfolio, the program management office (PMO) has established a plan for sustainment or knowledge transfer. Many projects will continue to operate past the term of the Cooperative Agreement, enhancing mobility for Columbus residents as the pandemic lifts. Other projects, including concepts within the original 15-project portfolio, have found new champions and are being executed under new conditions or delivery models not originally envisioned during the SCC.

5.1.5.1. CONTINUED IMPACT BY MULTIPLE SMART CITY CHALLENGE PROJECTS

The following projects that were funded through the SCC will continue through the support of the City and other long-term owners.

- **Smart Columbus OS –** The development of the OS has laid the groundwork for data-driven analytics to evaluate mobility and transportation investments. The integration of infrastructure and mobility data into the OS will help optimize safety and efficiency. These efforts will continue as the OS continues to build out use cases related to improving traffic safety, operations, and management.
- **Event Parking Management –** The EPM project has provided important enhancements to the ParkColumbus app. Post-demonstration, the app will continue to be one of the key solutions used by the City's Division of Parking Services to provide accessible, equitable and predictable parking options for all residents, guests and visitors.

- **Connected Vehicle Environment –** The roadside unit (RSU) and onboard unit (OBU) vendors are funded to operate and maintain their assets for a period of 15 months after the demonstration; Columbus is also continuing coordination with DriveOhio to pursue interoperability with other CV deployments managed by DriveOhio. The City of Columbus hopes to continue performance measurement activities to expand on the quantitative benefits of the CVE project's safety, mobility and data applications.
- **Smart Mobility Hubs –** Additional neighborhoods and mobility corridors are being studied as part of Columbus' mobility plan, LinkUS. Opportunities to include SMHs in LinkUS will be identified and implemented using the framework developed by the Smart Columbus Program and COTA's hub program. The Department of Public Service will take ownership of SMHs and coordinate implementation.
- **Multimodal Trip Planning Application –** Columbus has invested funds to sustain the Pivot application through January 2022. Basic features and functionalities will be enhanced, and the app will be improved to include gamification and rewards for using cost effective and environmentally friendly modes of transportation. Pivot will integrate with COTA's new fare product and incorporate booking with COTA Mainstream and COTA Plus services. New mobility providers will be added as needed.

5.1.5.2. ADDITIONAL CHAMPIONS IDENTIFIED FOR SEVERAL PROJECTS

For some projects, sustainability was not the goal in itself; but rather, projects sought to inform future operations and decisions. For MAPCD and PTA, the City will not be the long-term owner, but in both cases, the project outcomes were able to inform stakeholders involved with delivering services to specific groups.

The City has identified potential champions for projects incubated within the SCC Program:

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- **Smart Streetlighting –** The Smart Streetlighting project was intended to develop a lighting control system to upgrade operations and allow several departments interested in smart technologies to deploy them using the streetlighting system as power source and the Columbus Traffic Signal System for communications. While it was found to not be a logical fit within USDOT award, the City's Department of Utilities subsequently pursued a more robust and strategic streetlight plan. Following additional research and discovery in 2017 and 2018, Columbus published a smart streetlighting strategic plan in 2019. The strategic plan has since been put into action, as Columbus performed benchmarking with other cities, developed estimates for construction and established a prioritization plan. The effort is now planning a deployment including over 56,000 lights and 800 circuits, developed in concert with six departments in the City including the PMO. In addition, the public Wi-Fi component of the smart streetlights was incorporated into the broadband access plan developed by the Department of Technology.
- **Delivery Zone Assistance Application –** The systems engineering stakeholder engagement process conducted in late 2016 and early 2017 for this project did not reveal user needs for this solution. Subsequently, the project was removed from the portfolio in the summer of 2017. Since this time, however, the City's Division of Parking Services has revisited curb management. The City completed a six-month pilot of curbFlow from November 2019 to March 2020 during which it converted eight high-traffic areas into loading management zones where commercial, ride-hail and delivery drivers checked in via the curbFlow Driver App or reserved curb space in advance. The program successfully attracted over 2,150 commercial and on-demand drivers as registered users, with 18,200 legal check-ins for an average dwell time of seven minutes in the loading management zones. This is an area for future expansion within Columbus with a larger procurement being released by the City in March 2021 to continue to build out this concept.
- **Enhanced Permit Parking –** The City's Short North parking plan conducted and incorporated end-user engagement to inform more efficient parking permits and enforcement strategies. This plan included technology improvements to enhance parking such as pay-by-cell, pay-by-plate parking kiosks, and enforcement technology such as license plate readers. It was through the implementation of this enhanced permitting solution with Conduent as the prime contractor and ParkMobile as a subcontractor, that the EPM project vendor (ParkMobile) was identified and selected.
- **Oversize Vehicle Routing and Interstate Truck Parking –** For these projects, the concept development process revealed that the problem had a solution that could be solved with data, not necessarily technology. As the portfolio was being reconsidered in mid-2017, the OS was simultaneously evaluating user stories for deployment. The user needs for both projects indicated the issue was around a lack of visibility into data, which could be addressed by ingesting relevant datasets into the OS for discovery and use. Data pertaining to both challenges were ingested into the OS in 2018. In turn, the City was connected to Ohio Department of Transportation's (ODOT) Truck Parking Information Management System Dynamic Feed, which displays the status of available truck parking locations. In addition, through the May 2018 Hackathon, the OS added a Geotab dataset representing the parking locations for heavy duty trucks, including various metrics associated with these parking locations, popular hours, and vehicle types. The dataset is based on the previous 12 months of commercial vehicle data and is updated monthly.

5.1.6. Smart City Progress and Other Regional Collaborations

The SCC was part of a group of inspired and invigorated community initiatives that will explore what's next in urban mobility and technology. With the USDOT SCC complete and other efforts from the City, COTA, DriveOhio, The Columbus Partnership, MORPC and others established and gaining momentum, regional leaders continue to embrace new concepts and innovation. Community leaders have rallied around Columbus' emergence as a smart city. Policy makers have been inspired to create further change, advance new collaborative initiatives and advance transformative initiatives under development prior to Smart Columbus, like LinkUS.

Throughout the regional mobility ecosystem, the innovation spurred by the collaborative spirit of the Smart Columbus Program and regional partners continues. Some projects build upon the infrastructure assets and knowledge directly created by the SCC projects. Other partnerships will create new programs, introduce new solutions and promote adoption of new mobility technologies. Exciting initiatives underway throughout the region are summarized below.

5.1.6.1. AUTOMATED VEHICLES

- **Grants –** Since the deployment of Smart Circuit and the Linden LEAP, DriveOhio has won two grants to advance vehicle automation in the state and region:
  - The Automated Driving Systems grant in 2019 focused on “Deploying Automated Technologies Anywhere in Ohio” (*D.A.T.A. in Ohio*), particularly in rural environments and cooperative automation
  - The 2020 Advanced Transportation and Congestion Management Technologies Deployment (ATCMTD) grant will help advance truck automation on I-70 between Indiana and Ohio.
- **SMARTCenter –** In July 2019, the Transportation Research Center (TRC) in East Liberty, Ohio, opened its SMARTCenter or Smart Mobility Advanced Research Test Center – a dedicated 540-acre AV and CV test area within the TRC’s immense 4,500-acre proving grounds. This $45 million investment established TRC as North America’s largest AV test facility.

5.1.6.2. CONNECTED VEHICLES

- **33 Smart Mobility Corridor –** A $5.9 million demonstration from USDOT helped initiate the 33 Smart Mobility Corridor led by DriveOhio, the City of Marysville, Union County, and the City of Dublin. This project has created a 35-mile corridor with redundant fiber network and 87 dedicated short range communications (DSRC) devices along US-33 through Marysville and Dublin. Both Columbus and Dublin are planning on extending the fiber network and DSRC installations to the point where they meet in Northwest Columbus to create an expanded, interoperable connected vehicle environment. The 33 Smart Mobility Corridor partners were recently selected for an opportunity with the Institute of Transportation Engineers to conduct interoperability testing among these deployments.
- **Vision Zero –** Joining a national road safety initiative, Columbus’ Vision Zero Columbus Action Plan lays out a strategy to pursue the goal of zero fatalities and serious injuries from crashes on Columbus streets. The action plan identifies a high-injury network of City streets that have a higher density of fatal or serious crashes where injuries and fatalities frequently involve vulnerable road users such as pedestrians, bicyclists and motorcyclists. With the current CVE infrastructure remaining in operation (and licensed by the Federal Communications Commission (FCC) for the foreseeable future), this infrastructure and potential future expansion of the CVE network can help reduce crashes and improve safety for all roadway users, as current and potential safety applications will be evaluated against the specific use cases identified through the action plan.

5.1.6.2.1 Bus Rapid Transit Expansion

Although there is uncertainty around DSRC as the adopted CV technology in the long-term, it has been proven that its use for non-proprietary transit signal priority can be effective and cost-efficient. As COTA expands its Bus Rapid Transit and Columbus and the state explore the future of CV technology, the potential remains for COTA to continue as an important partner in adoption.

5.1.6.3. ELECTRIC VEHICLES AND ELECTRIFICATION

Since the Paul G. Allen Family Foundation and USDOT demonstrations have been completed, DriveOhio has developed and documented a statewide approach to EV charging[42], and published an EV strategic plan[43]. The purpose of this plan is to assess needs for electric vehicle (EV) charging, primarily along Ohio's highway corridors. Corridor charging requires relatively high-power Direct Current Fast Charging (DCFC) stations that can rapidly deliver significant added range to EVs at locations that are easily and quickly accessed by motorists. This report identifies DCFC gaps in Interstate, U.S. Highway and State Route corridors and identifies options to fill them. With the Paul G. Allen Family Foundation demonstration priorities focused on both fleet and consumer electric vehicle adoption and expansion of charging infrastructure, the electrification priorities relate directly to DriveOhio's planning efforts in this area.

In addition, a total of three to four locations will be evaluated each year by COTA for the placement of EV Chargers. These charging stations will be accessible to the public to help reduce the emission levels and promote a cleaner environment. In coordination with MORPC, a goal of ten locations is anticipated to be electrified.

5.1.6.4. SHARED MOBILITY

- **LinkUS** is Central Ohio's transformational and comprehensive prosperity and mobility initiative unveiled in June 2020, and is jointly led by the City, COTA and MORPC. LinkUS is intended to serve as an umbrella program for all mobility implementation efforts in the region. The innovative approach will include high capacity and advanced rapid transit, bikeways, green space, pedestrian improvements, and focusing development along major roadway corridors throughout Central Ohio. The initiative is actively seeking solutions to address traffic congestion, provide new mobility options, expand access to resources, and promote equity and economic vitality along key regional growth corridors. Projects such as SMH, MMTPA and CVE provide examples for such solutions and hold potential to contribute to what will be deployed through this promising initiative.
- **C-Pass Program –** The C-Pass program, sponsored by COTA, the Capital Crossroads Special Improvement District and MORPC, has provided 45,000 downtown Columbus employees with free bus passes since its launch in 2017. The program provided a creative solution to parking challenges experienced downtown, and it was the first program of its kind that enabled downtown property owners to fund free, unlimited access to transit for employees. This program has been extended through 2025, providing expanded mobility options for Columbus employees as they begin to return to work downtown, as the pandemic subsides.
- **Growth of the Shared Mobility Ecosystem –** The number of mobility providers serving Columbus has expanded greatly during the past five years. Through active attraction efforts, Columbus introduced Zipcar, and Bird, Lime, Spin and Link scooter and bike-sharing services to the market and fostered the foundation of homegrown startups EmpowerBus and SHARE. In addition, the sustained operations and maintenance of Pivot includes enhancements to continue to accommodate and integrate the ever-changing landscape of mobility providers.

[42] *https://drive.ohio.gov/wps/portal/gov/driveohio/about-driveohio/news-and-events/ohio-announces-statewide-approach-to-ev-charging*

[43] *https://drive.ohio.gov/wps/wcm/connect/gov/4a58a392-917f-4735-8438-bfdbb3f0b7bd/2020-06-26_EV_Charging_Study.pdf?MOD=AJPERES&CONVERT_TO=url&CACHEID=ROOTWORKSPACE.Z18_M1HGGIK0N0JO00QO9DDDDM3000-4a58a392-917f-4735-8438-bfdbb3f0b7bd-nc08aJ2*

5.1.6.5. INTELLIGENT MOBILITY

- **Pivot Routing Engine –** The Pivot routing engine developed in the MMTPA project uses machine learning to make recommendations based on traveler habits and preferences, and to provide trip optimization based on data from INRIX and transit on current and historical conditions.
- **Parking Prediction Model –** An algorithm created through the OS and EPM projects was a key component delivered in July 2020 for the ParkColumbus application's "parking availability" feature. It was built to allow alterations for changes to the amount of data that is used for the prediction. The Machine Learning Training Process occurs daily using the City parking meter transaction data, ParkMobile parking transactions, real-time sensor data and the City of Columbus parking meter inventory/configuration datasets from the OS and integrates this information into the ParkColumbus application for presentation to travelers.
- **Waycare Pilot –** In December 2020, COTA announced the implementation of a traffic management and predictive analytics artificial intelligence system. The first-of-its-kind project will improve traffic safety and reduce travel time for transit users across 13 central Ohio counties through a cloud-based connected mobility platform owned and operated by Waycare Technologies. The project is made possible by a $1.7 million Integrated Mobility Innovation Demonstration Research Grant awarded by USDOT to COTA and 13 additional partners. The system will be the largest of its kind in the country and the first involving public transit agencies.
- **COTA Fare Management System Upgrade –** In summer 2020, COTA initiated procurement of a new fare management system. In working on the MMTPA and Common Payment System (CPS) project requirements at the start of the program, COTA's existing fare system was a constraint that was difficult to accommodate into the user needs and requirements. However, the COVID-19 pandemic placed an increased priority on contactless payment for COTA. With this concern, as well as a desire for other improvements to fare management, COTA approved a contract with Masabi in October 2020, which is expected to be completed in 2021. This new solution will be account-based and will use an open architecture that is scalable to support growth, and capable of accepting a variety of payments, in alignment with the original concept for the CPS.

5.1.7. Smart Columbus Work Will Continue

Beyond the term of the SCC award, the Smart Columbus initiative will continue as a public-private partnership co-led by the City of Columbus and The Columbus Partnership, with a charge that extends beyond mobility and positions the organization as an agile, collaborative innovation lab for the city of the future. As such, Smart Columbus will serve to accelerate and advance what's next at the intersection of technology and community good. Projects already underway at Smart Columbus include a broadband pilot that will help to close the local digital divide, an app that will facilitate the record sealing process to create pathways to the middle class, and a corporate renewable energy buying program that will improve local air quality and fight climate change. Although the Smart Columbus Experience Center been closed to the public on account of the pandemic, the organization also plans to reopen it to the public in the fall of 2021 with new educational experiences on urban technologies.

5.1.8. Program Investment Multiplied Initial Grant Value

Direct investment, job creation, and improvements in transit productivity produced a 1.77 to 2.58 multiplier effect for the initial $40 million grant. As described in the economic impact assessment conducted by OSU detailed in **Chapter 4**, the $40 million grant investment by USDOT plus over $15 million in City, ODOT, Franklin County and OSU contributions had a multiplied impact when invested in the work to deliver the program.

The analysis calculated a short-term impact of $173.29 million in gross metropolitan product (GMP), $51.51 million from direct investments by the program, $121.88 in indirect effects, through impacts on the supply chain and increased household spending induced by the increased supply and income. Furthermore, investments by the program are likely to generate a job increase of 2,366 jobs, 58 directly employed to staff the program and its projects, and the remaining 2,308 attributable to the indirect effect on the affected sectors through the supply chain.

While OSU researchers concluded that the long-term projected economic impacts of the Cooperative Agreement investment are more difficult to quantify, it can be seen that the reduction of urban traffic congestion and the increase of urban transit services captured in the projected program evaluation would eventually lead to a corresponding ratio of changes in productivity and household expenditure on urban transit services. As such, successful deployment of the projects and utilization of the services could generate a $671.28 million increase in GMP, and 7,039 jobs, which can largely be attributed to the productivity improvement in urban transit-related sectors.

Overall, the multiplier of USDOT program investment was found to range between 1.77 and 2.58, with an average rate of 2.24, which suggests that each dollar of the program is associated with a $1.77 – $2.58 increase in value-added to the local economy.

This economic impact analysis is limited in that it does not account for economic shocks associated with the COVID-19 pandemic and relies on continued adoption of the demonstration projects. However, it provides a helpful analytical framework for the economic impact assessment of smart city investment, both for Columbus and for other cities evaluating smart city investments.

5.1.9. How Intelligent Transportation Systems Benefit People

Beyond the safety and customer satisfaction data, and past the economic impact analysis, there are stories of Columbus residents who benefitted from the projects. These residents experienced the potential that intelligent transportation systems hold firsthand, through an easier way to get to work or entertainment, through access to food services that were needed during the pandemic, through investments in their Columbus-based tech or automotive businesses, or through hands-on job skills training. Following are the ways that Columbus residents described the impacts of this program.

> **This has been such an awesome opportunity, to not only help myself, but help the community I grew up in. I'm also a licensed minister so I feel like I have a calling to serve and this is the perfect opportunity and the perfect way to be able to help. It's kinda mind blowing how you're able to prosper through something as tough as this. Because of this job I've been able to buy a new house for my grandkids and purchase a new vehicle. I am forever grateful.**
>
> *Sherri, Linden LEAP Operator, Linden*

> **I used to use Transit but with the real-time bus information, route information, and voice navigation in Pivot, I'm a convert. I even share it with my fellow bus riders so they don't have to guess which bus to take or what stop to get off at.**
>
> *Morgan, Essential Worker, Linden*

> **My partner and I are avid Columbus Blue Jacket fans and now that games have started up again, I can use ParkColumbus to reserve a spot in advance so I'm not stranded by the bus after hours or paying surge pricing for a ride-hail home.**
>
> *Robert, ParkColumbus User, Merion Village*

> **I quickly adapted to getting the alerts in my vehicle. There were occasions when it made me aware of things I wouldn't have noticed otherwise. I particularly liked the red light warning alert.**
>
> *Tonie, CVE Study Participant, Reynoldsburg*

> **It was nice to have Linden noticed for something positive. And now Linden is a leader in this space and has the infrastructure, data, and experience to be prepared for future innovations.**
>
> *Ms. Peg, Linden LEAP participant, Linden*

5.2. LESSONS LEARNED AND RECOMMENDATIONS

The SCC was a once-in-a-city's-lifetime opportunity. Seventy-eight cities vied for the award and the opportunity to demonstrate how intelligent transportation systems, powered by data, can forever change the ways people move through American cities. The issuance of the Challenge presented an opportunity to rally Columbus' public and private sectors together, to cast a vision for the future of mobility in the city, where all people can access opportunity through tech-enabled mobility. After the challenge was won, the financial award provided generous resources to demonstrate a robust array of emerging technologies and show the human impacts they can achieve, and as demonstrated by the financial analysis, created cascading opportunities through direct and indirect investment.

As outlined in **Section 5.1**, winning the SCC was an incredible opportunity for Columbus, and the implementation of USDOT Cooperative Agreement created opportunities and yielded successes that will benefit the region for years to come. This unique platform also created a rich opportunity for learning, which came both through successes and challenges. The SCC model presented unique obstacles that other cities can now be prepared to navigate in future challenge-style programs.

Representatives of the new administration have suggested that federal infrastructure and COVID-19 recovery funding may be delivered through similar city challenge-style programs. As such, following is a summary of lessons learned because of the SCC, and recommendations for cities and federal agencies for how to navigate them in the future. Perhaps more importantly, even state and locally-funded programs are frequently developed under time pressures to fit into legislative, funding, or election schedules, and the lessons below may apply to these situations as well.

5.2.1. Projects and Agreements Should be Adaptable

Competitive applications are developed under time and pressure. With the time constraints to develop the application, stakeholder engagement was minimal in some cases or based on previous studies in others. It was necessary to make assumptions given that the timing was insufficient to pursue direct end-user engagement or detailed technical reviews with industry vendors. As a result, the die was cast early for several projects absent of details that would fully inform project deployment.

After award, the delivery team conducted robust end-user engagement during the first 12-18 months of the Cooperative Agreement delivery period, and in so doing, found that some programs, such as the Transit Collision Avoidance System, were not needed at the time by the users they intended to serve; and others, such as Smart Streetlighting and Enhanced Permit Parking, could be better implemented outside the parameters of the program. Similarly, as the delivery team vetted available AV technologies, the team found that the intended shuttle route at Easton was too challenging for the technology available at the time. As a result, several projects needed to be revised, or found more fitting homes outside the Smart Columbus portfolio through the portfolio revision process in 2017.

Realigning the program and removing projects from USDOT Cooperative Agreement optimized the program and demonstrated the value of the systems engineering process in directing the evaluation process. When reorganizing the portfolio, the City placed value on objectively evaluating technology and only moving forward with solutions that were truly ready for demonstration and evaluation and also aligned with user needs.

Should future federal funding be awarded through a challenge-style application process, federal agencies can elicit the best proposals by not only asking applicants to inform their proposals with end-user feedback, but also by allowing the time for this feedback to be sought and incorporated into the application timeframes. This could be pursued by requiring dedicated engagement to inform a City's application, or that applications are informed by past engagement efforts. Applications could be judged by a City's demonstrated experience capturing, interpreting and acting in response to direct user input. In addition, asking cities to identify user-informed use cases that technology will solve (in the instance of the CEAV project, FMLM connections) but not specific deployment conditions (the Easton route) will provide cities with the flexibility needed to design for user needs and technical capabilities, creating a more dynamic and flexible path to technical deployment.

Cities must also be empowered to move at the speed of technology and change course if needed. Shared scooters arrived in Columbus with little forewarning and required the City to adapt the MMTPA and SMH projects accordingly. Federal agencies may support the evolution of projects based on user needs by providing grant-winning cities with flexible, adaptable agreements that accommodate and encourage Agile and Hybrid systems engineering approaches so that collaboration with not only end users but partners and potential solution providers can be leveraged for the project, and that the process for developing guiding agreements and policies (and identifying the parties that should be involved in this process) can begin as soon as possible.

5.2.2. Use Cases and Requirements Should Guide Technology Provisioning

The highly publicized challenge also broadcast to technology vendors in the intelligent transportation space that Columbus was an attractive early customer for the urban technologies they were building. Technology providers signed on with USDOT to provide free services as key leveraged partners, but they came with caveats that may not have aligned with user needs or program policies, and some vendor agreements did not comply with City bidding requirements. Other technology providers descended upon Columbus pitching "hammers in search of nails" – promising interesting technologies that may not have aligned with real user needs or Columbus' equity-driven priorities.

The Truck Platooning project was removed from the program, as the key leveraged partner was unable to support a twelve-month demonstration. The user needs specified a need for higher level control, management, and recordkeeping for truck platooning, and Peloton was one of the only vendors with a market-ready system. Although the City completed a request for information (RFI) to evaluate alternatives, these alternatives did not reveal another solution that was technically ready for a longer demonstration.

Similarly, the Transit Collision Avoidance System project was originally intended to be completed in partnership with Mobileye for COTA. As the concept was developed, it was determined that the Mobileye solution did not meet COTA's user needs, specifically around the type of collisions that COTA identified as problematic. While COTA was interested in collision avoidance systems, the solution could not be pursued in partnership with Mobileye.

As such, it is important for cities to approach technology and equity projects with strategic outcomes and user needs in mind, and to bid technologies accordingly, to ensure that technology is designed and built for human outcomes, rather than to be an attractive tech showpiece that doesn't deliver on community priorities. In provisioning technology projects, it is important that cities set the table within the context of user needs, and challenge vendors to demonstrate how their solutions address them. This can be done through vendor days, RFIs and very specific expectations articulated and contracted in the procurement process.

5.2.3. Establish from the Outset a Scalable, Supported and Adaptable Program Management Office

Establishing a robust PMO with dedicated resources while having access to subject matter experts (through procurement or the funding agency) in communications, technology, partnerships, finance and procurement is critical from the beginning. The early conservative spending on the program by the City was not necessarily a demonstration of efficiency, but rather reflective of the time it took to outline the appropriate positions and fill them with dedicated staff and consulted resources.

Based on the experience of the Columbus team, any city pursuing a robust smart cities program should carefully and intentionally envision a PMO structure from the start, and be ready to scale and jump into execution. Getting the right people on the bus and in the right seats was something that took time, as the City only learned who it needed as it began delivering the program. A lack of staff and misaligned assignments contributed to issues early on, which the restructure of the PMO addressed.

Through the PMO restructure, the City hired its first ever Chief Innovation Officer, reporting directly to the Mayor, to lead the program. It also hired a Program Manager with vast experience in program management, federal funding, and resource management. The City identified seasoned project managers and complemented internal staff and new-hire staff with contracted consultants, including program management and subject matter experts to assist with development of all projects and Cooperative Agreement requirements and deliverables.

As the revised PMO staff came on board in mid-2017 and fully engaged to deliver the program, it was necessary to step back to determine if the portfolio of projects at the time were meeting the overall program goals. As the PMO found as they began to move through delivery, sometimes the hypothesis cannot be solved with the available solutions. With the new PMO on board and in consultation with USDOT, the City halted the Smart Columbus Program in the fall of 2017 to finalize its foundational documents (e.g. project management plan, systems engineering management plan) and realign and reimagine a program that better aligned with the goals of both the City and USDOT. The result was a refined portfolio of nine projects instead of fifteen.

Consultants were also critical to this effort, given the focus on emerging technologies that had largely been demonstrated only within the private sector before the SCC. Procuring technical expertise from consultants and contractors was critical, as was access to technical experts at the Federal level. These individuals can augment a city-led PMO and provide a depth and breadth of knowledge and experience that complements local partners. Balancing in-house staff with consulted resources is situational. The City chose to contract due to the limited availability of experts nationally and time-limited duration of the program.

In addition to being able to adapt internally, cities awarded long-term federal funding should anticipate administration changes and be prepared to adjust. While the SCC was awarded under the Obama administration, the program evolved immediately after the administration left office. This program was the vision of the USDOT Office of the Secretary and was envisioned to be a collaborative effort between Columbus and USDOT. Ultimately, the scope of the program changed both due to the administration change as well as delivery challenges previously described. Both impacted the program and were changes that the PMO adapted to during the delivery of the program.

5.2.4. Collaboration and Partnerships Maximize Impact

Transportation innovation goes far beyond the confines of city government. The SCC presented a unique opportunity to bring partners from across Columbus' public, private, academic and non-profit sectors together to align around a common goal of improved equity though enhanced mobility. The robust partner coalition augmented the knowledge, reach and efficacy of the program, and enabled more impactful outcomes. Following are recommendations for collaborating and driving action through a regional partner network across a community's mobility ecosystem:

- **Grantors –** For cities pursuing grants or other funding, identify a champion on both sides of the arrangement. Developing a solid working relationship between grantor and grantee is critical to success. Scheduling regular face-to-face time (post-pandemic) and making these meetups an opportunity for open dialogue in addition to programmatic updates, can help champions freely discuss challenges and successes, brainstorm and evaluate alternatives and build team camaraderie.
- **City Departments –** Ensure buy-in from leadership and identify champions in pertinent city departments. Any department that could be affected needs to understand a program's goals and requirements for success. Having the PMO report through the City's Chief Innovation Officer (CINO) and directly to the Mayor expedited and facilitated collaboration across City departments.
- **Public Agencies –** Synergies should be identified and communicated between transportation systems management and operations (TSM&O) and smart city concepts to identify common concepts and activities. TSM&O is better understood by infrastructure owner-operators, such as transportation management centers, transit agencies, human services transportation providers (e.g., senior shuttles, medical transportation), and private taxi operators. Commonly, emerging technology concepts are not as well understood by these groups. The stakeholder engagement efforts for CVE and CEAV focused on identifying these common elements and communicating them to these partners with the goal of building acceptance and support of the new technologies.
- **Transit Agencies –** Transit agencies must be involved in project development for technology programs relevant to smart cities transportation programs, particularly when trying to achieve goals related to equity and efficiency. COTA served as a partner for the MAPCD, SMH, CVE, and MMTPA/CPS projects. COTA agreed to allow some of its transit centers to serve as SMH locations, and also allowed their training center to be used for the MAPCD travel training. DSRC onboard units were installed on COTA's fixed route, paratransit, and supervisor fleets for the CVE project. And COTA's fixed route service is at the core of the MMTPA (Pivot app).
- **Regional Planning Commissions –** Regional planning commission coordination must occur to ensure project visions align with regional transportation initiatives. MORPC was a partner in the development of MMTPA and encouraged Columbus to integrate with its carpooling platform, Gohio Commute. Being a significant data collector and generator in Central Ohio, MORPC provided valuable input and guidance in the development of the OS.

- **Research Institutions and Universities –** Research institutions should be included in program plans to provide expertise and resources to assist with evaluation. OSU served as the Principal Investigator for both the MAPCD and PTA projects and served a key leadership role in measuring the performance of the program overall as well as for most of the projects. OSU was particularly skilled in administering surveys to users and participants. The City also engaged with OSU's Center for Automotive Research as part of the safety management process. For CEAV, OSU completed a detailed analysis and simulation of the potential route and was also a key contributor on the incident review panel. Using local institutions also boosts regional expertise and builds capacity for future technology projects.
- **Private Sector –** Involving local corporations and businesses can help increase user buy-in and access to resources. The Columbus Partnership is a nonprofit entity that represents 75 of the largest businesses in Columbus. The Columbus Partnership provided input on the sustainability and long-term plans for the OS and worked to elevate program visibility both regionally and nationally. The Columbus Partnership also tracked regional investments aligned with the Smart Columbus Program. Not all investments were directly spurred by the SCC win but aligned investment in Smart Cities was calculated to be about $762 million. [44]

Key examples of projects that relied on collaboration and partnerships include the CVE and CEAV projects, which required regulatory and policy changes from the state. Having already engaged with these stakeholders made it a seamless process to coordinate with ODOT/DriveOhio and defer to their leadership on efforts to permit and register AVs. In addition, as the City had no experience serving as a transit operator, it relied on its partnership with COTA to help guide operational development and procedures. Having an experienced operator like COTA guide the City and provide insights was invaluable to the program's success. MORPC's experience with data was unparalleled and helped guide the later stages of the OS. MORPC has memorialized its commitment to sending data to the OS as the region looks to undertake data regionalization efforts.

5.2.5. Refinement of Processes and Delivery Methods is a Key to Success

Managing technology deployments is a new skillset for many cities; embracing new skills, policies, and practices will help cities implement technology more successfully.

In implementing the SCC portfolio, the City of Columbus sought to deploy the most robust array of emerging mobility technologies of any city in the country. In so doing, employees of the PMO identified new systems, skills, and methodologies often found in the tech sector that are currently uncommon in many public works departments. Embracing the following methodologies and practices can help cities deploy technology projects more successfully. Refining these processes has created a "muscle memory" for tackling future-forward challenges that will benefit future technology deployments by the City's Department of Public Service and beyond.

5.2.5.1. DATA PRIVACY

USDOT identified the importance of data management and privacy in the Cooperative Agreement, recognizing that to be a smart city, there must be a focus on providing open and transparent data to the general public. This requires the development and implementation of comprehensive data management and privacy policies and strategies. One success of the program was the creation of the data management and privacy plans, which consider a citywide approach to these activities, beyond the projects.

[44] https://smart.columbus.gov/funding-sources/acceleration-fund

Columbus engaged with subject matter experts from the public, the private sector, and educational institutions to help create the Data Privacy Plan, Data Management Plan, and Data Privacy Policy. These plans and policies were included in contract documents and ensured that data collected and stored on the OS would not include any type of identifying information about individuals. The "de-identified" data can be leveraged by the City going forward to assist with informing policy and decision-making while ensuring individuals' privacy is protected.

Figure 5-8: A Replicable Approach for Cities to Data Privacy

Source: HNTB

5.2.5.2. AGILE METHODOLOGY

Emerging technologies demand adaptability in deployment strategies. The traditional systems engineering approach provides structure which is beneficial to document user needs and requirements for solutions that may not exist, and a means by which to evaluate potential solutions that do. Systems engineering provides traceability testing and delivery. However, traditional systems engineering is not well suited for projects that are leveraging IoT, software applications, and off-the-shelf solutions. In the case of the Smart Columbus program, many projects were constantly challenged to accommodate and adapt to changing user needs, stakeholder circumstances, and technology readiness. This is an area where agencies should continue to seek improvement and innovation, as future opportunities prioritize not only technology but also delivery and financing. Whereas traditional systems engineering is tailored toward a linear design-build-operate-maintain process, the predefined users and use cases that the traditional V-Model approach requires cannot possibly cover the needs of broader (and changing) stakeholders and yet-undefined use cases over the course of a multi-year innovative technology project.

Agile methodology allows for a "fail fast, recover quickly" style of development. Unlike V-Model, which begins tests after an initial product is completed, Agile tests continuously as more features are developed and released in the sprints. In this methodology, user stories replace user needs and system requirements, and represent the smallest unit of work; it is a goal for the product expressed from the user's point of view as opposed to a feature. Agile also emphasizes early delivery of a minimum viable product which is an early version of the product that contains the minimal functionality and features to be usable by early customers. This way, these customers can then provide feedback for future product development.

The V-Model systems engineering approach establishes a process for identifying user needs, system requirements, and testing. This approach was used for projects that required the installation of physical infrastructure, particularly the SMH and CVE projects. This approach worked well and minimized post-construction changes such as reconfiguration of equipment placement or removals of infrastructure.

For projects involving software development or the procurement of off-the-shelf products, an Agile or Hybrid approach is more beneficial. Projects like MMTPA, EPM and PTA engaged stakeholders to identify user needs and created a Concept of Operations, which could be easily converted into requirements for a Request for Proposal. This process still ensured traceability but saved time and resources by not producing a System Requirement Specifications document, and allowed the vendor development teams to collaborate and iterate on product features and functionality. A Hybrid or Agile systems engineering approach is better prepared to accommodate changes, as both apply a risk-based, iterative process that consistently seeks to identify and include emerging needs and requirements in the final solution.

City staff from the PMO are now better trained in Agile and Hybrid methodologies and can apply this knowledge on future tech-forward projects the City implements.

5.2.5.3. RESIDENT ENGAGEMENT AND COMMUNICATION

For iterative technology projects, resident engagement must be a continuous, two-way conversation. The City found it critical to engage early and often with all program stakeholders. Communications should start even before funding is identified because isolating the problems to be solved and identifying the best solutions may take time.

The City found it important to align with stakeholders on goals and project locations early in the process, as user needs may grow or change from what is first assumed. To the extent feasible, stakeholders should remain engaged as the project continues development so that changing needs can potentially be incorporated. Be adaptable to changes not just during the systems engineering process, but throughout design, construction, and deployment as well, to accommodate the pace of emerging technologies.

When communicating specific projects, the City found it best to use an integrated set of paid, earned, owned and shared communications strategies (described in **Section 3.2.4**) that leveraged innovative, data-driven approaches. Communication can lessen distrust of technology and improve adoption, particularly where outreach results in co-creation and a level of mutual comfort with the audience/neighborhoods being reached. Recruiting Beta testers during app development helps to capture feedback on the User Interface and User Experience. This is valuable information to help shape the look and feel of the app while addressing user needs.

Communication within the team was also essential to strong external communications. Communicators must work closely with technical leads to understand project schedules to ensure the key pieces of engagement occur at the right time.

5.2.5.4. HOLISTIC PORTFOLIO MANAGEMENT

Creating a technology innovation environment within an existing government structure can be challenging especially when coupled within the confines of the requirements of a Cooperative Agreement – it's not an open-ended award. The Cooperative Agreement, while flexible, defines the scope of work to be completed. For this reason, it is especially important when advancing multiple technology and mobility projects, especially those that are integrating multiple modes, to use a holistic technology approach with common goals, providers, and solutions that potentially contribute to multiple projects. Coordination with the efforts and projects taking place elsewhere in the agency and through other funding sources can be leveraged and brought together for the benefit of all stakeholders and projects.

The City found it valuable to create a holistic program-wide narrative to create awareness and excitement for the entire portfolio of projects. As project delivery shifted from winning the challenge to establishing a conceptual portfolio to launching specific projects, communications similarly shifted from community focused to end user focused. The City found it particularly helpful to create multiple touch points, such as quarterly meetings, Beta tests, and project demonstrations to continually gather feedback on user experience.

Since the program was a combination of pilots, studies, and long-term deployments it was also critical to communicate the differences between the project types, understand their points of intersection, and articulate the vision for project demonstration and sustainability after the agreement period. This sometimes required multiple champions: a singular champion within the recipients' organizations, advocating for the overall program, individual champions to drive each project forward to success, and a champion within the sponsoring organization who works consistently and collaboratively with the recipient to simultaneously provide guidance and oversight. With projects having multiple champions and potentially owners, partners and stakeholders are sometimes willing to participate but may feel less responsibility in final outcomes. For key partners, using incentives and identifying benefits and returns are key to engaging this passion and keeping the project a priority within their organizations.

The holistic approach to managing the program helped the project team identify opportunities. Coordination with the efforts and projects taking place elsewhere in the City and through other funding sources can be leveraged and brought together for the benefit of all stakeholders and projects. For the SMH project, COTA was able to leverage funding from AEP to install electric vehicle supply equipment at the Northern Lights Park & Ride. The SMH project was also able to leverage an existing agreement between Experience Columbus and Orange Barrel Media to install Interactive Kiosks (IKE) Smart City kiosks. [45] The CVE project continuously coordinated with DriveOhio and the 33 Smart Mobility Corridor which allowed the City to use existing Radio Technical Commission for Maritime Services (RTCM)/ Security Credential Management System components that DriveOhio procured for the benefit of CVE.

5.2.5.5. UNDERSTANDING THE APPLICATION OF STANDARDS

Existing standards and references may not cover the scope of emerging technology efforts. As such, agencies should stay engaged and aware of standards and policy development efforts and seek alternatives and insights from the private sector if gaps are identified. In Columbus' experience, the National ITS Architecture was just one example available, and there was a need to customize the initial version of the program architecture to accurately describe all projects. The pace of updates to the architecture in 2019 and 2020 did capture some of these customizations, but there is additional benefit to agencies engaging with standards development organizations, other agencies and private industry to ensure consistency outside of published standards. Another specific example of this was an initial recommendation to rely on the National Institute of Standards and Technology Special Publication 800-122 and 800-153 as a guideline for a risk-based approach to protecting the confidentiality of personally identifiable information. As the PMO engaged with SMEs from private industry in developing the Data Privacy Plan, it was found that this standard (published in 2010) was not typically being followed by the privacy and security industry. Although still referenced, it was the lessons and guidance from the private sector that provided the most insight into creating a flexible and sustainable approach to data privacy.

[45] *Orange Barrel Media is a Columbus-based marketing company that provides innovative commercial messaging. Its subsidiary company, IKE Smart City, provides an interactive kiosk platform. The agreement between Experience Columbus and Orange Barrel Media enabled the placement of numerous IKE kiosks to be placed around Columbus.*

5.2.5.6. CREATING THE BUSINESS CASE FOR SUSTAINMENT

Projects benefit from a large-scale owner to help build the business case for the end solution. Knowing that there will be a larger deployment after a successful pilot makes outreach, agreements, and adoption easier and more productive, and is necessary for long-term/sustained operations.

In the case of the SMH project, the City and COTA have the common goal of adding more mobility hubs around Columbus, and it will make sense to continue coordination to leverage both efforts (Smart Columbus Program SMHs and COTA's mobility hub project) for the mutual benefit of both owners. Conversely, the City also observed that development could have been approached differently to better engage with stakeholders, particularly mobility providers. Accommodating partial integration of these providers early in the MMTPA/CPS development could have helped build the business case for their long-term participation, facilitating the finalization of agreements and ultimately achieving the full integration of these providers into the system through a common account.

5.2.6. Accommodating Challenges

Technical challenges will always occur in innovative programs seeking to deploy emerging technology in new and different ways. For the program, there were both anticipated and unanticipated challenges, some of which are described below.

Aspects of the MMTPA project that made it challenging to implement were the same attributes that made it novel to the industry— similar apps had not yet been created because they required an unprecedented amount of collaboration and private sector negotiation. It was anticipated that integrating multiple mobility providers into the MMTPA would be challenging as issues around data and account coordination had been well documented and it was known that mobility providers each have separate systems that require a flexible and adaptable system for integration. For CPS, the time to first identify the complex network of agreements and the time it would take to negotiate each one was underestimated, and ultimately led to significant delays that pushed the project into the onset of the pandemic, which then further contributed to the ultimate stalling of the CPS portion of the project.

Due to close collaboration with information available through USDOT and its Connected Vehicle Pilot Program (CV pilots), it was anticipated that the project team should allow a conservative amount of time for application development, integration and testing, and the original schedule allowed for multiple on-site testing sessions for the CVE project. What was unanticipated was two things, first, during the CVE development, the FCC voted to reallocate the majority of the 5.9 GHz safety spectrum that currently allows life-saving Vehicle-to-Everything technologies to work without interference. To ensure sustainability, the City and contractors had to reevaluate DSRC communications. The team adjusted by broadcasting all messages on Channel 180 from the RSUs to the OBUs, including the Wave Services Announcement, MAP message, signal phase and timing, RTCM, signal status message, and over the air updates. With the extra time planned in the schedule, the minimal delays did not impact the schedule significantly.

While all projects face challenges, the COVID-19 pandemic was globally unanticipated, clearly demonstrating the fact that some risks can be planned for and others cannot. COVID-19 impacts on contractors and mobility providers, along with the drastic reduction in travel, caused the PMO to delay launching projects and reduced the data collection for the program overall, due to both the reduced duration of demonstration and the prolonged reduction in travel in the region. The result was smaller sample sizes and less statistically valid project findings. The strength of the program and the sustainability of many of these projects will allow the City to continue to evaluate the outcomes of these projects, as the deployments become more integrated into Columbus' existing operations.

Beyond the immediate delay of launching the SMH project (originally planned for April 2020), the pandemic created challenges (or worsened existing challenges) for the following projects:

- For EPM, the vendor for the solution, ParkMobile, had an immediate impact on their business – with the overnight downturn in parking, the shift in their financial position precluded them from continuing to use contract development (third party) resources for the ParkColumbus application. Work continued, but at a slower pace due to staff reductions.
- For CEAV, in May 2020, the National Highway Traffic Safety Administration approved the safety mitigations put into place following the incident in February 2020. However, by this time, stay-at-home orders and social distancing guidelines made passenger service on the Linden LEAP impossible to resume. The project team quickly engaged with stakeholders to identify alternate use cases, finalizing the change to using the shuttle for food pantry delivery to the community from St. Stephen's Community House. This alternate use case was approved by USDOT and launched in July 2020.
- For MMTPA/CPS, the pandemic exacerbated risks and challenges that the team was already working actively to mitigate. Existing project risks, although in mitigation at the onset of the pandemic, caused key partners to scale back or even withdraw their commitment to the demonstration and post-demonstration project. As a result, the PMO had to evaluate the overall project and made the decision to remove the CPS project but continue MMTPA.
- For CVE, the impact of the pandemic was two-fold. The project was one of the first to be impacted in late 2019 when the virus delayed shipments of OBUs from China, delaying the start of installations. Second, travel restrictions and stay-at-home orders from March to June 2020 prevented the project team (including the vendor teams who were based in Texas) from working together in-person in Columbus as originally intended. These activities continued remotely, albeit at a slower pace.

While these same circumstances are unlikely to impact similar initiatives, it is important that PMOs be ready to adapt to forces outside their control. Strong partnerships and end user engagement, as well as a collaborative grantor-grantee relationship can help make necessary shifts possible. For MMTPA, providing an opportunity to pay for mobility services through Pivot was a key goal; however, in collaborating with mobility providers, Pivot was able to "deep link" to mobility provider applications for payments. For CEAV, solving FMLM challenges was a primary need and regular communications with stakeholders allowed the shuttle to shift its service to deliver food to the neighborhood.

5.3. SUMMARY

As this report details, the SCC gave Columbus a unique and special opportunity to demonstrate how emerging mobility technologies can improve safety, mobility, opportunity, environment, agency efficiency and customer satisfaction. More broadly, delivery of the portfolio has aspired to demonstrate how responsive, innovative and safe mobility solutions can empower residents to live their best lives. The original portfolio of 15 projects was very ambitious, and ultimately needed a re-evaluation and realignment to better align with USDOT and City priorities. The 2017 program restructuring eliminated, consolidated and added a project to the betterment of the program. The PMO was better able to focus on the eight projects within the portfolio and align those projects with user needs – to better serve residents.

As a result, many of the projects from this portfolio will be sustained to continue to serve the mobility needs of Columbus residents, and the partnerships and project management methodologies honed through the program will benefit the community for years to come. The City is also proud of the fact that even for projects that were removed from the portfolio, many were implemented through other means, both by the City and by its partners. Through the program implementation, the projects have created short- and long-term impacts for the Columbus community, and also created a replicable playbook that other cities may build upon to have similar effect in cities nationwide.

Chapter 6. Smart Columbus Operating System

6.1. PROJECT OVERVIEW

The Smart Columbus Operating System (SCOS), commonly referred to as the Operating System (OS), forms the backbone of the other seven Smart Columbus projects. In the Smart City Challenge application, the City saw an opportunity to create a shared platform for all U.S. Department of Transportation (USDOT) Smart City Challenge data and data from other regional entities. The OS, presented as the "Integrated Data Exchange" in the application, was envisioned to host performance metrics, serve the data needs of public agencies, researchers and entrepreneurs, and serve as the foundation for other program projects.

The role of the OS evolved during the Cooperative Agreement, ensuring it was meeting the needs of the other Smart Columbus projects. There were multiple OS vision workshops conducted in 2016 and 2017 to define the platform's initial mission. Participants included the City of Columbus, key leveraged partners, and a wide variety of stakeholders (representing the private sector, academia, other cities and City departments, community organizations,) and consultants and subject matter experts. The project was conceptualized and delivered in an Agile development methodology from the start, first delivering a minimal viable product (MVP) of the initial data environment for demonstration to USDOT in December of 2017 while simultaneously continuing to refine the final vision and architecture for the OS. The reorganization of the Program Management Office (PMO) in 2017 bolstered the City's technical resources and subject matter expertise, along with procuring additional development resources. Stakeholder engagement and working groups continued throughout this time (in 2017 and 2018) and in September 2018, released the final vision of the OS:

> *"By ingesting, visualizing and sharing open, secure data, the [Smart Columbus] Operating System will give public sector officials and private sector innovators the insight they need to use data to empower our residents; through improved mobility, and establishing a platform for solving complex urban challenges in cities."*

The goals and deliverables of the OS were defined as follows:

- **USDOT Project Support –** One measure of the success of the OS is how well it supports the USDOT goals and projects specified by the Cooperative Agreement.
- **Analytics/Data/Visualization –** Having analytics and visualization tools that are not only functional, but also accessible and user friendly, is key to increasing the use and utility of the OS for projects beyond the Cooperative Agreement.
- **Open-Source –** Building the OS using open-source components ensured that the OS could be migrated across technology platforms without vendor lock in, reducing licensing costs for software, and providing access to the OS technology to the public. This results in a platform that is scalable, extensible, portable, and sustainable, with code will be published to a repository so that other cities can leverage and contribute to it.
- **Sustainability and Productization –** The long-term goals for the OS was that it would (1) be maintained after the demonstration to support regional initiatives and data sharing, and (2) would be transferrable for use by other regions looking at transforming their transportation systems with data.

- **DevOps –** DevOps is the simultaneous development of software (DEV) while managing and running the operating software (OPS)[46]. This approach facilitates faster implementation and adoption while allowing additional development and delivery of a stable, bug-free platform.
- **Privacy/Security –** Creating active data privacy and management policies and ensuring compliance; ensuring proper security protocols in place to prevent Personally Identifiable Information, Payment Card Industry, and Personal Health Information data from being accessed by unauthorized users, and creating a full administrative environment in place for security, operations, and user access.

With this revised vision, dedicated subject matter expertise in the PMO and an expanded development team under contract, the OS data platform 2.0 was launched in April 2019, signifying the official start of the project's demonstration. The latest version of the OS is not only an open data portal, hosting archive data for performance measures and streaming datasets for both projects and other data from around the City, state and region. Key highlights include its streaming data services, such as the real-time project data ingested from the Connected Vehicle Environment (CVE) and live map feed of Central Ohio Transit Authority (COTA) bus locations. Other features include browser-based data querying and visualization tools, notably the parking prediction model that powers the Event Parking Management project (EPM) ParkColumbus app's "parking availability" feature.

The OS serves as the City's incubator for developing and exploring new concepts in data-driven transportation infrastructure. With a priority on resiliency and scalability, the OS was built to be cloud-agnostic and open source. In terms of delivering on the desired outcomes of the Smart Columbus Program, the OS team also engaged regularly with the user community to assess customer satisfaction and agency efficiency and how the OS could positively impact these outcomes. **Figure 6-1** shows the areas from where data is collected, as well as the wide range of possible users. The resulting data can be analyzed to provide useful information for policy-making and other decisions, as well as providing the information needed to operate and measure the performance of both regional and smart cities data driven projects.

CONTRIBUTIONS OF THE OS

- Hosts the predicted availability model for the EPM which uses multiple datasets and ML to calculate on-street parking probability
- Hosts numerous streaming datasets and subsequent generated reports for the CVE project
- Powers the City's Division of Infrastructure Management Employee and Work Order Allocation Dashboard to help identify areas for efficiency improvement

[46] https://en.wikipedia.org/wiki/DevOps

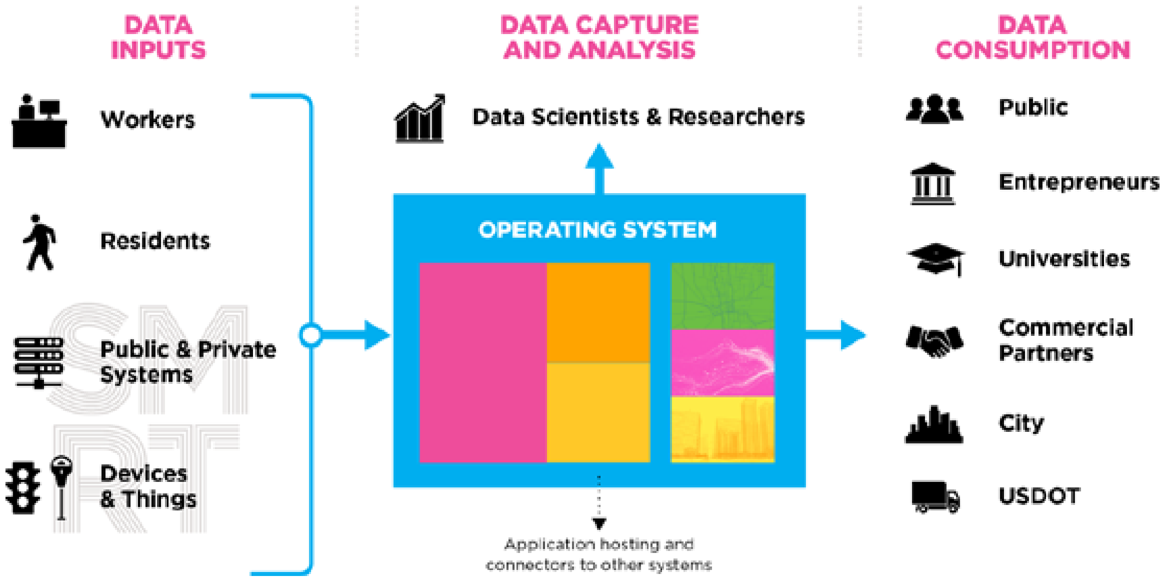

Figure 6-1: Smart Columbus Operating System Overview

Source: City of Columbus

6.2. DEPLOYMENT SUMMARY

This section describes the development approach for the OS, insights into the OS components and functions, highlights from the demonstration and the role of communications.

6.2.1. Systems Engineering Approach

There were multiple delivery teams that led the development of the OS. In the early phases of development, the City's Department of Technology (DoT) led the project, including the development of the early Product Vision document. The planned approach to development of the OS (then known as the Integrated Data Exchange (IDE)), was the V-Model systems engineering approach. However, as the project got underway in late 2016, the project team was encouraged by USDOT to use an Agile project delivery approach. As the City was unfamiliar with this approach, initial efforts more closely resembled a combination of Agile and V-Model. Ultimately, with the new staff in place in 2017, the Agile delivery methodology was fully implemented. This approach is fully defined in **Chapter 2**; the Agile development and delivery approach is better suited software development, as it focuses on small task sizes, incremental development, testing and delivery so that functionality can be deployed sooner, while maximizing stakeholder engagement and feedback, flexibility for change and managing risk.

The Agile development process applied by the OS project team was characterized by iterative software releases, allowing the developers to swiftly evaluate how well each released feature supported both the project and program needs, and course correct as necessary to deliver value quickly. The project team frequently deployed new versions and patches to production multiple times a week or even in a single day. Small increments of work were continually discovered, developed and deployed to production. As illustrated in **Figure 6-2**, the cycle of improvements is as follows:

- **Feature Discovery –** System functions are identified, evaluated, and prioritized to determine which features are needed.
  - The delivery team creates user "personas" to understand how the work to be performed aligns to the needs of the intended end users.

  - The development team creates detailed “story maps” that described how each area of the platform would work, individually and in concert.
  - The story maps are then used to build a “backlog” of all the development tasks that would be necessary to build each feature.
    - Each development task is represented and can be justified by tying it to a user persona. For example, “As a Data Curator (persona), I need a way to ingest data into the OS, so that I can share data with the public.”
  - The backlog would be prioritized to meet roadmap deliverables.
  - The backlog serves as a “to do” list of tasks that will be completed in each sprint.
- **Feature Development –** Features are built and delivered through Continuous Integration (CI).
- **Feature Deployment –** New features and patches are deployed to production and demonstrated as they become available.
- **Feature Reiteration –** Features are tested with users for feedback, which is then prioritized and incorporated into future iterations.

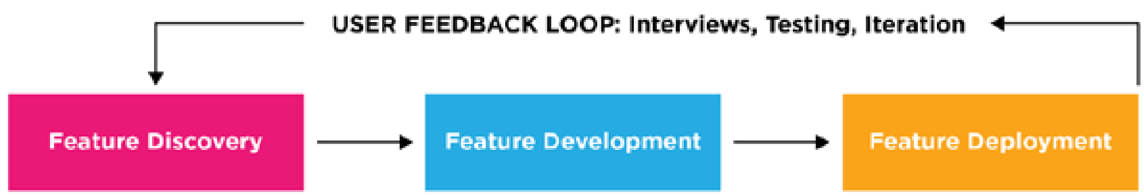

Figure 6-2: Software Delivery Overview

Source: City of Columbus

The initial systems engineering effort in 2016-2017 resulted in the definition of the initial framework of the IDE, including the product vision, platform architecture, and use cases. Early examples of use cases included food access, transportation, and interstate truck parking assistance. From there, the initial build phase started. The IDE was built leveraging the open-source data portal software CKAN[47] beginning in June of 2017. CKAN was selected as the initial platform candidate as it was one of the leading open-source platforms in the world, used by the governments of the United States, Canada, the Australian state of New South Wales, and many others. It was easy to launch, maintain, ingest data, and was widely supported by the open-source community of developers and data enthusiasts. Along with CKAN, Joomla was used as the initial content management system for the MVP that was delivered in December 2017.

With the new PMO leadership and structure in place as well as a consultant project team in place, a comprehensive, six-month, rolling product roadmap was developed in early 2018, and it remained in place for the duration of the project providing visibility into the planning and release process. Project deliverables were scheduled for each stage and posted to the Smart Columbus Program website and briefed to USDOT in the format outlined in **Figure 6-3**.

[5] https://ckan.org/

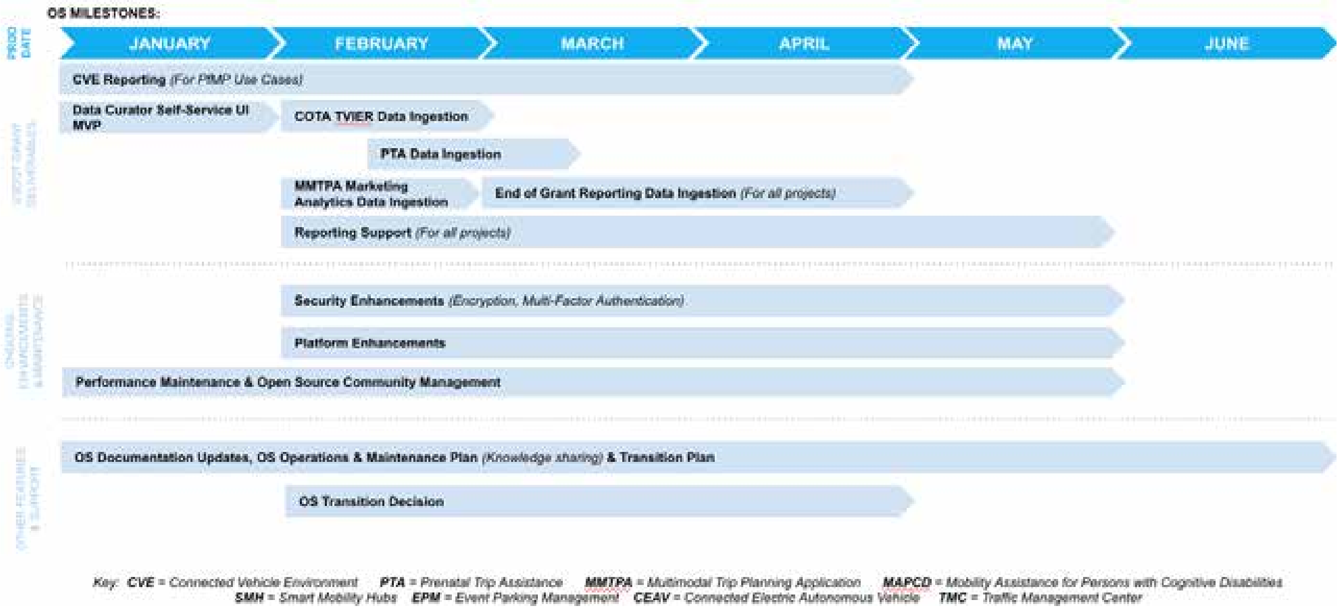

Figure 6-3: Smart Columbus Operating System Roadmap (Jan 2021 – June 2021)

Source: City of Columbus

Other consistent development and management elements that took hold with the new PMO leadership and project team in 2018 included:

- The project Architecture Review Board (ARB), which documented in the change log all major changes to the project roadmap. The ARB was created to ensure the process followed the proper accountability protocols and the project did not change on a whim, abandoning the original project goals. Over time, members of the ARB included the product owner, solution architect, technical leads, and program manager.
- Monthly public demonstrations, which explained the work performed the month prior, as well as showcasing new features, to a group of participants that included USDOT, OSU, COTA, Mid-Ohio Regional Planning Commission (MORPC), members of the Technical Working Group (TWGs), and the general public.

In April 2019, to more accurately meet the streaming data needs of the projects, such as CVE, as well as to address scalability requirements, the OS was rebuilt and relaunched as "Operating System 2.0," a scalable, cloud-agnostic, open-source data platform, based upon the Elixir programming languages and microservices described in the introduction. While these technologies are not as common in the public sector, these open technologies are often favored by leading technologists in innovative organizations. This brought these innovative engineering capabilities to the OS, enabling the data curation, visualization and machine learning (ML) capabilities that were originally envisioned. With the enhanced platform (the OS 2.0) complete, the project entered demonstration. As a truly Agile project, however, the OS continued development of use cases, identification and ingestion of new datasets, and completion of remaining system components, all in the same iterative approach outlined in **Figure 6-2.**

6.2.2. Project Launch

Unlike other projects, the OS had several different events that signified different elements of the system being released into production:

- The Minimum Viable Product (MVP) of the OS was presented to USDOT and made publicly accessible in December 2017. Consistent with Agile project development, the OS was available to the public with datasets hosted for download and use while other components of the system were still in development.
- A more public launch following the onboarding of Pillar Technologies (now Accenture) in May 2018 when the Operating System 1.0 (CKAN) was publicly deployed this launch also reflected the re-branded platform that was created with the final OS vision. The launch announcement, “Smart Columbus unveils first version of the OS,”[48] was covered locally and nationally, most notably by the Associated Press.
  - To encourage technologists from across the community to engage with the content within the OS, the Smart Columbus Program staff hosted a Hackathon the weekend of May 18, 2018. During the Hackathon, approximately 80 software developers, hardware tinkerers and other tech enthusiasts came together to explore the data and prototype the ways it could be used.

In April 2019 when the platform was transitioned from CKAN to Elixir, messaging throughout the OS website was updated to educate users on the enhanced functionality to indicate the OS 2.0. This also began the official performance measurement (or demonstration period) for the OS. The launch and subsequent relaunch announcements were also conveyed to the public in conjunction with the Smart Columbus Program and The Columbus Partnership via press releases, email newsletters, as well as multiple social media posts. Content about the OS was also posted to the Smart Columbus Playbook maintained by The Columbus Partnership.[49] As with the launch of the re-branded OS in May 2018, a second Hackathon event was hosted by OSU in November 2019.

6.2.3. Project Demonstration

Following the launch of the OS 2.0 in April 2019, the OS team continued to practice Agile software delivery methods, and CI of new features and bug fixes into the code base. Key new features and system elements that have been developed include the visualization and query tools, the data curation user interface (UI), parking predicted availability model, the agency dashboard for the City’s Division of Infrastructure Management.

This subsection describes this CI and development process in greater detail. It also provides more detail on the OS components and functions and how they were leveraged by the other Smart Columbus projects to provide greater insight into the final product that will remain in operation after the program concludes in May 2021.

6.2.3.1. CONTINUOUS INTEGRATION

In software engineering, CI is the practice of merging all developers' working copies to a shared mainline several times a day. This allows for fast feedback to be collected from users, which can be quickly used to improve future iterations of the software. Even after the OS entered demonstration, the project team continued to expand both functionality of the OS as well as user stories.

The OS’ problem statements were framed as “value stories” to define the goals that the OS would achieve, the project outcomes it needed to support, and data contributors and consumers contributing and using data. These were developed through various stakeholder engagement activities (including early workshops

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[48] *https://smart.columbus.gov/news/smart-columbus-unveils-first-version-of-the-smart-columbus-operating-system*

[49] *Examples of postings are at https://smart.columbus.gov/playbook-assets/smart-columbus-operating-system/essentials-of-the-smart-columbus-operating-system*

and later TWG meetings). The value stories were used to gain consensus and alignment across the development teams and throughout the duration of the project. For example:

- *As Smart Columbus, I want* the necessary features and data activated within the OS, *so that* the other USDOT projects and other Smart Columbus projects can leverage the OS to deliver value to the people of Columbus.
  - **Example**: Parking Prediction Model powering the ParkColumbus “parking availability” feature.
- *As Smart Columbus, I want* to make meaningful data accessible *so that* I can have a positive impact on the lives of Columbus residents.
  - **Example**: Connected Vehicle Environment Reporting, Connected Electric Autonomous Vehicle reporting
- *As a Smart City, I want* to build a financially self-sustaining platform with an environment in which people are empowered to serve themselves resulting in faster solutioning and minimized overhead costs.
  - **Example:** Open-source, cloud-agnostic platform with playbook/Operations & Maintenance plan.

6.2.3.2. COMPONENTS AND FUNCTIONS OF THE OS

There are three core functions of the Operating System as it relates to the data it stores and services it provides: data ingestion, storage and retrieval (microservices), and data query and visualization.

6.2.3.2.1 Data Ingestion

The OS was designed from the start to ingest a large amount of data. During the development phase, a process was designed to regulate the intake of data, to be run by data curators. The role of the data curator is to oversee all data ingested into the OS to ensure it aligns with the policies and practices outlined in the Data Privacy Plan (DPP) and the Data Management Plan (DMP). These plans, discussed in more detail in **Chapter 3**, ensure that Personally Identifiable Information (PII) is stripped from the data before it is added to the OS. Specific responsibilities of the data curators include:

- Determining the value and sensitivity of the data (assessing whether it contains PII)
- Assigning a classification to the data (whether it should be public or private)
- Ensuring that the metadata and data dictionaries are complete
- Facilitating the actual ingestion of the data and making it available for consumption.

The data curation and ingestion workflow is shown as a workflow diagram in **Figure 6-4.** There are a few additional areas of explanation to accompany the figure. These include:

6. For the first step, data intake may be requested from either an internal or external source.
7. The level of access to the data is classified as either "public" or "private."
8. The data curator UI serves as the tool to coordinate, establish and configure the data ingestion pipeline. The dataset ingestion details are entered into the curator UI (entering the address to download the dataset, as well as whether it is a one-time or a recurring ingestion).
9. How soon the dataset is available within the OS depends on the size and format of the data – smaller dataset formats that are 1-150 megabytes are typically available within a matter of minutes. Larger datasets that are 1-20 gigabytes may take 2-3 days. Streaming datasets, such as the Parking Prediction datasets, take longer to set up and ingest; however, the data flowing into the system is available in near-real-time.

The OS features a visual interface for ingesting and editing datasets. **Figure 6-5** shows the page for uploading datasets (along with a list of some of the datasets in the OS). **Figure 6-6** shows another screen of the dataset entry process.

The interface requirements were determined by several workshops and interviews with the project data curators referenced above. Over time, additional features were added based upon recommendations and feedback from testing with the data curators. The interface allows anyone, regardless of programming ability, to submit datasets for review, curation and ingestion. This process not only made it more useful for users engaging in data discovery and analysis but also served as a check that the data met the plans and policies outlined in the DMP and DPP regarding risk.

Key reasons that a dataset may be rejected from ingestion through the data curation process include:

1. PII
2. Data that may be harmful to any person, group, or organization
3. Data that may be considered critical of City infrastructure
4. Errors
5. Inaccurate data
6. Duplicate dataset
7. Incomplete data
8. Failure to complete metadata

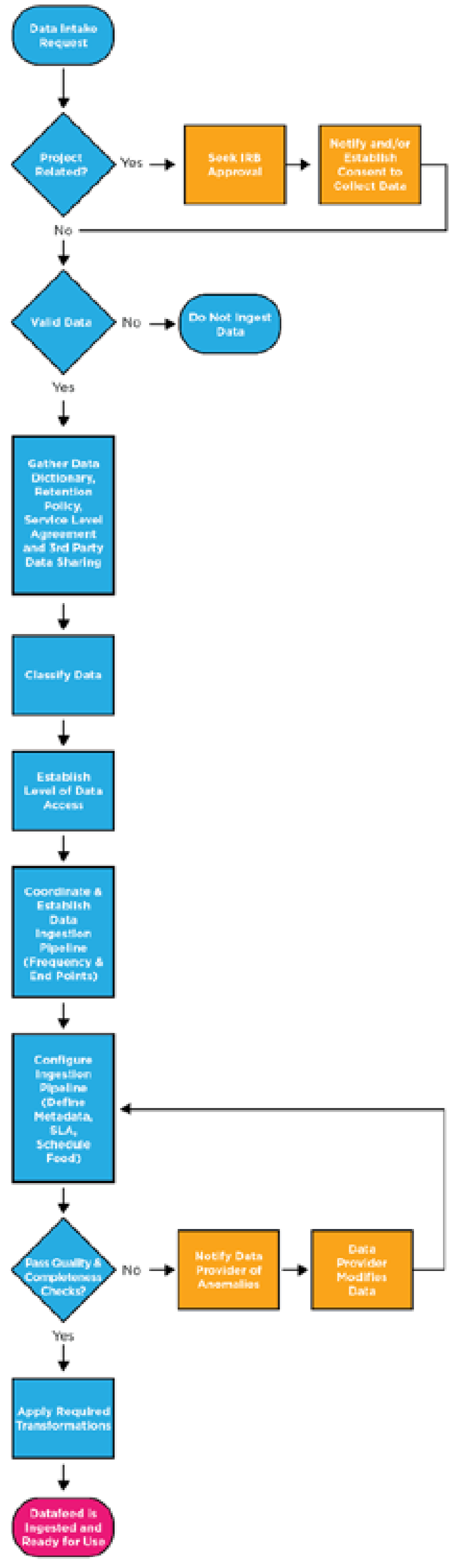

Figure 6-4. Smart Columbus Operating System Data Curation Workflow

Source: City of Columbus

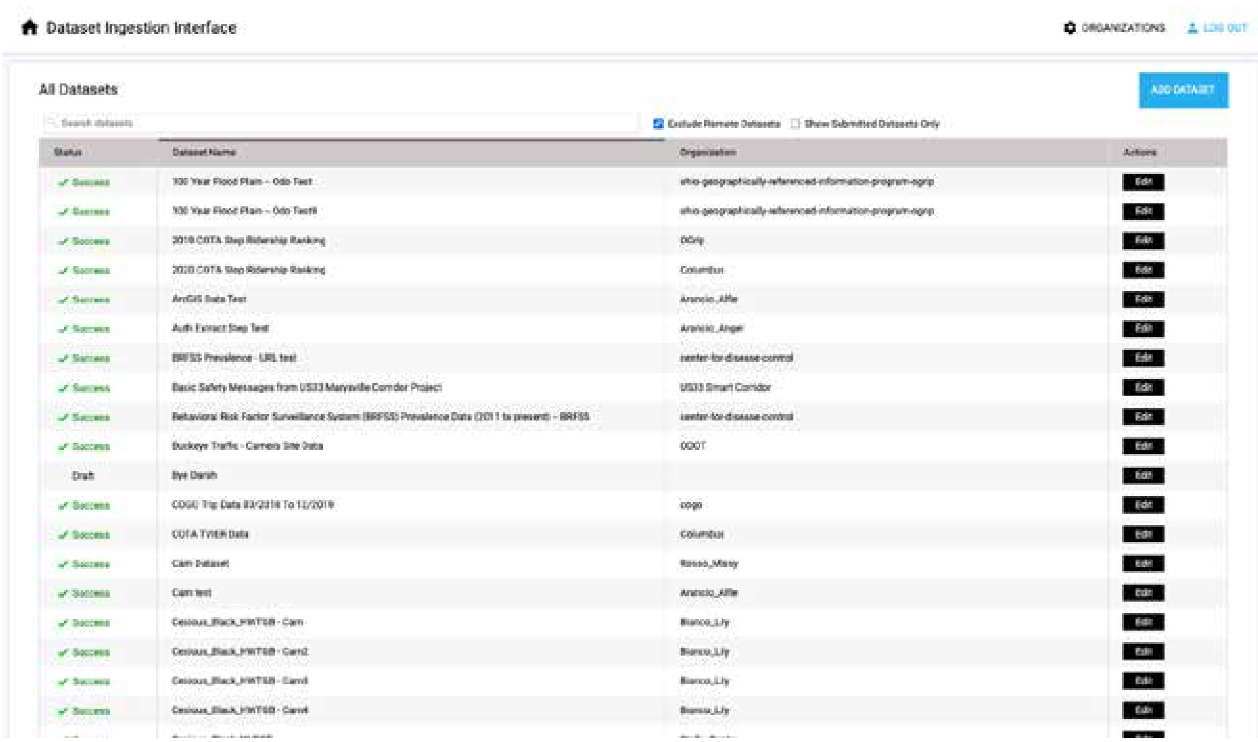

Figure 6-5: Smart Columbus Operating System Dataset Ingestion

Source: City of Columbus

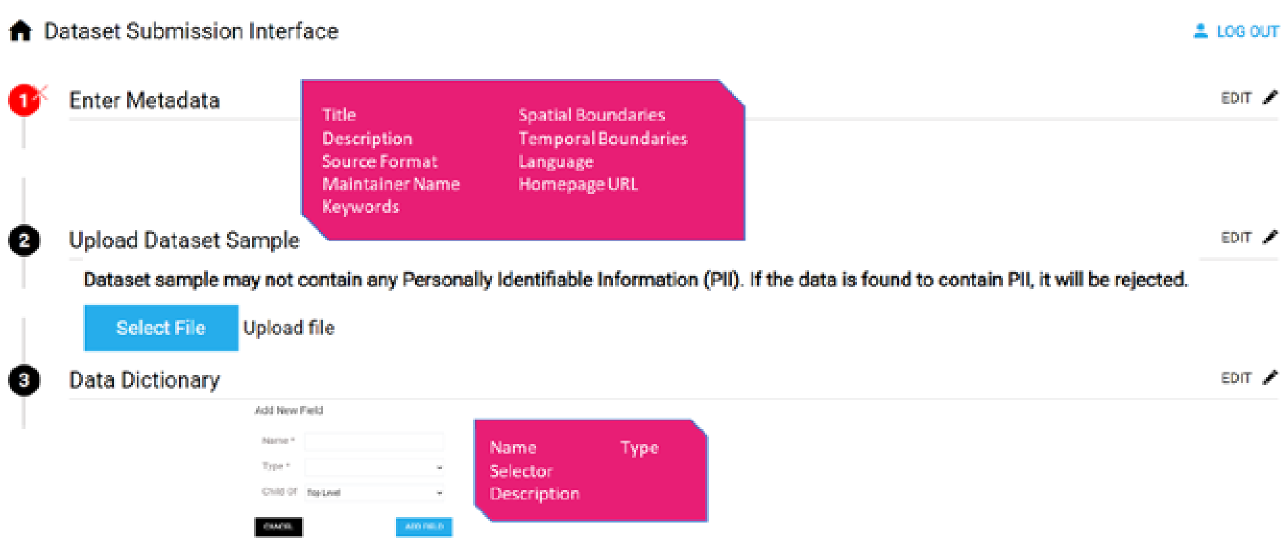

Figure 6-6: Smart Columbus Operating System Self-Service Data Submission

Source: City of Columbus

6.2.3.2.2 Data Storage and Retrieval (Microservices)

The OS is built upon the principle of ***microservices*** architecture, where a series of individual processes work together to fulfill the goal of storing and retrieving data. The microservice architecture was selected because each component operates individually from the rest of the system; it is modular – an entity may not need or want all the microservices; therefore, they would install only what they want and need. Individual microservices also improve fault tolerance – if one of the component microservices fails, the rest of the system remains operational. These architecture components were evaluated by the project's Information Architect, Technical Leads, project partners, and City representatives. The components had to meet the following criteria: open source, widely used in the development community, and having well-documented support for implementation and maintenance. This would allow Columbus, and any future city that implements an operating system, to easily find the development resources and support it needs.

The following core microservices and UI components constitute the SCOS architecture:

- Elixir[50] – Many of the microservices are written in Elixir – a dynamic, functional programming language originally designed for use in the telecommunications industry. Elixir was selected as it has been hardened over decades of use, and if there is an error in the process, it will automatically restart that process.
- Kafka[51] – is the communications mechanism, developed by Apache, that allows the SCOS microservices to communicate with each other.
- Kubernetes[52] – is a system for automating the deployment, scaling, and management of the SCOS microservices.
- Presto[53] – is a big-data query engine developed by Apache that allows the SCOS to search large data stores, in this case Amazon Web Services storage, and send the results back to the SCOS front end (UI) for use.
- React JS[54] – is the web language used to build the front end of the OS. When a user browses, generates queries, or downloads a dataset, they are using the React JS portion of the SCOS.

Figure 6-7 provides a visual overview of how these individual elements form the system architecture for the OS.

50 *https://elixir-lang.org/*

51 *https://kafka.apache.org/*

52 *https://kubernetes.io/docs/concepts/overview/what-is-kubernetes/*

53 *https://prestodb.io/*

54 *https://reactjs.org/*

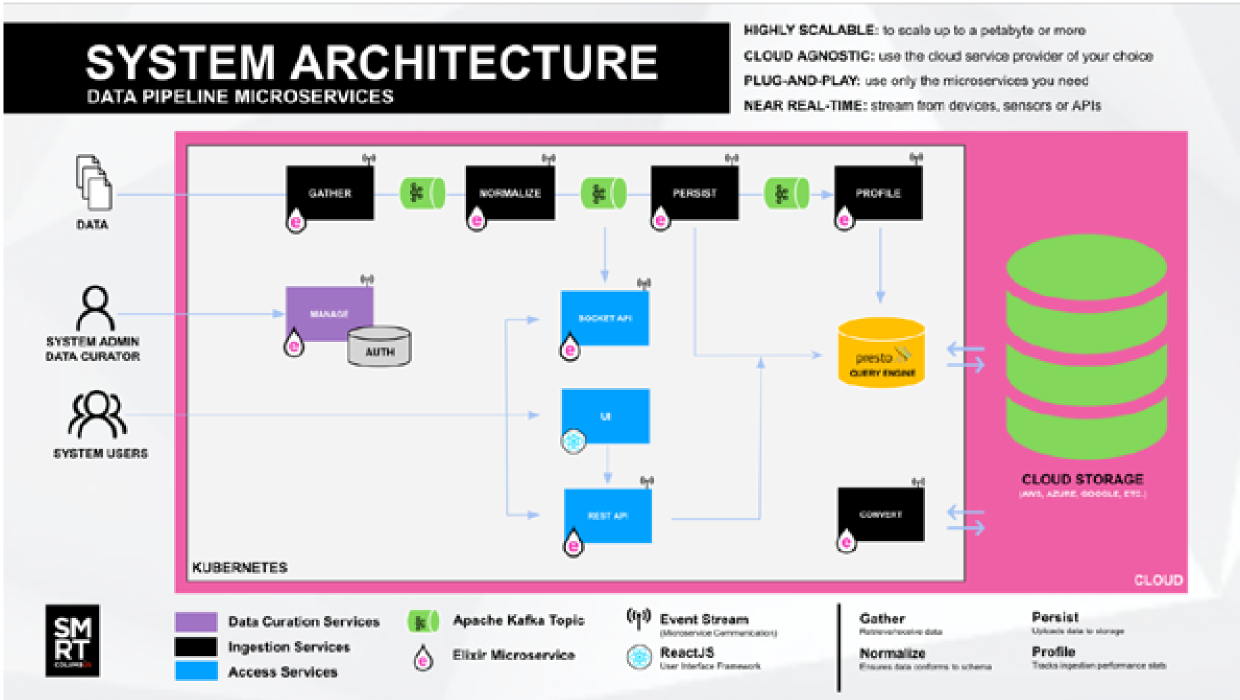

Figure 6-7: Smart Columbus Operating System Architecture

Source: City of Columbus

6.2.3.2.3 Data Query and Visualization

The OS offers the ability to query data and create visualizations using the following components:

- **Querying –** An SQL-based querying mechanism was built into the platform to allow users to refine SCOS data to produce meaningful insights. The SQL language was chosen because it is the primary language used by data experts worldwide to query databases. **Figure 6-8** shows the SCOS' querying UI.

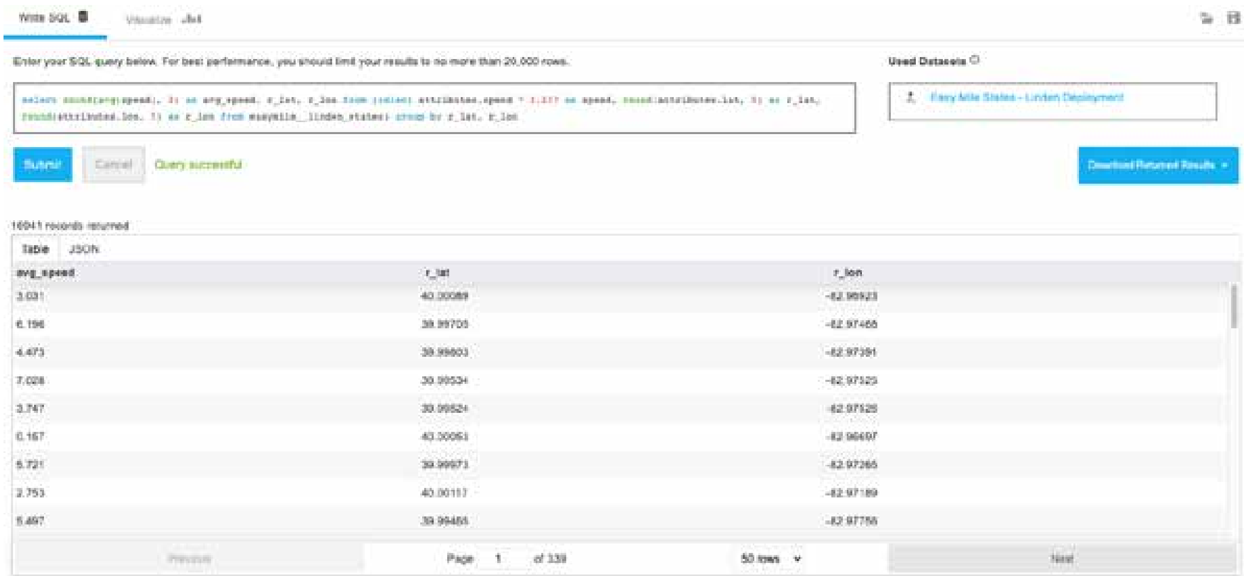

Figure 6-8: Smart Columbus Operating System SQL (Querying) Workspace

Source: City of Columbus

- **Visualizations –** The SCOS uses or facilitates two types of visualization software: Plotly and Tableau. **Figure 6-9** shows an example of a visualization created by the OS for parking meter transactions.
  - **Plotly –** The SCOS development team evaluated several visualization tools, including Kepler[55] and Plotly.[56] The team selected Plotly, an open-source web-based visualization tool, because it could be integrated as a feature within the source code for the OS, providing a seamless experience for the user. Because it is embedded within the platform, users can manipulate the data without leaving the platform, saving time, and potentially lengthy download times (depending on the size of a dataset).
  - **Tableau –** Tableau is a leading tool used by data scientists for product visualizations. The OS features a web-based Tableau connector[57] to allow users to connect their desktop Tableau application to the SCOS directly.

[55] https://kepler.gl/

[56] https://plotly.com/

[57] https://data.smartcolumbusos.com/tableau/connector.html

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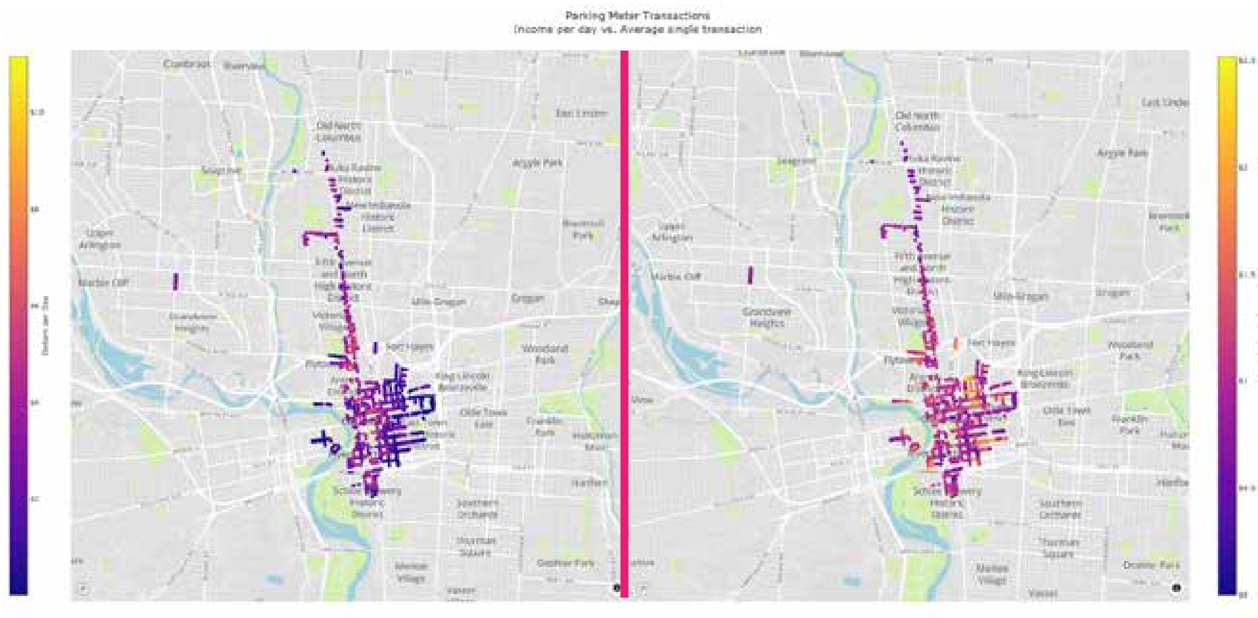


Figure 6-9: Smart Columbus Operating System Visualization Workspace (Heat Map of Parking Meter Transactions)

Source: City of Columbus

6.2.3.3. HIGHLIGHTS OF DEMONSTRATION

6.2.3.3.1 Performance Measures

A critical role of the OS during the demonstration phase of the Smart Columbus Program is the archive of all project-generated data. Links to examples related to specific Smart Columbus projects are in **Table 6-1**.

Table 11: Performance Indicator Data

Dataset	URL
Mobility Assistance for People with Cognitive Disabilities (MAPCD)	https://discovery.smartcolumbusos.com/dataset/able-link/mapcd_trip_data
Multimodal Trip Planning Application (MMTPA)	https://discovery.smartcolumbusos.com/dataset/pivot/mmtpa
Linden Linden Empowers All People (LEAP) Automated Shuttle	https://discovery.smartcolumbusos.com/?facets%5Borganization%5D%5B%5D=Easy%20Mile
Smart Mobility Hubs (SMH)	https://discovery.smartcolumbusos.com/?facets%5Borganization%5D%5B%5D=Ike
Event Parking Management (EPM)	https://discovery.smartcolumbusos.com/?q=parkmobile&page=1&sort=relevance
Connected Vehicle Environment (CVE)	https://discovery.smartcolumbusos.com/dataset/smart_columbus_cve/captcha

Dataset	URL
Prenatal Trip Assistance (PTA)	https://discovery.smartcolumbusos.com/dataset/smrt_program/prenatal_trip_assistance_pta_application_trip_data

Source: City of Columbus

6.2.3.3.2 Project Support

During the Demonstration phase, the OS's querying and visualization capabilities were used to provide various functions for projects (such as EPM), dashboards, charts, and graphs to support agency partners such as the Division of Infrastructure Management, and reporting for the program projects, including MMTPA, SMH and CVE.

EPM PARKING PREDICTION MODEL

A key component delivered in July 2020 was the parking prediction model for the ParkMobile app's "parking availability" feature for the EPM project. The code for the predictive availability model is open source and was custom developed for the EPM project (described in **Chapter 12**). It was built to allow alterations for changes to the amount of data that is used for the prediction. The retraining of the predictive availability model over time allows it to adapt to gradual changes in parking activity; however, changes to the model itself (in terms of how the prediction is calculated or algorithm being used for the model) are not automated and require work from a data scientist. The ML Training Process uses the IPS Group parking transactions, ParkMobile parking transactions, and the City of Columbus parking meter inventory/configuration datasets from the OS to create the predictive availability model. As shown in **Figure 6-10**, the ML Training Process initiates the calls to the OS to get data and uses that data to build the Model. ParkMobile or a third-party user initiates the call to the Application Programming Interface (API), which in turn initiates a call to the Model to get the prediction needed to be returned (that is, the predicted availability percentage requested). ParkMobile receives the predictive availability model output/results for visualization in the EPM mobile app in real-time via a Representational State Transfer Application Programming Interface (REST API) that is hosted by the OS.

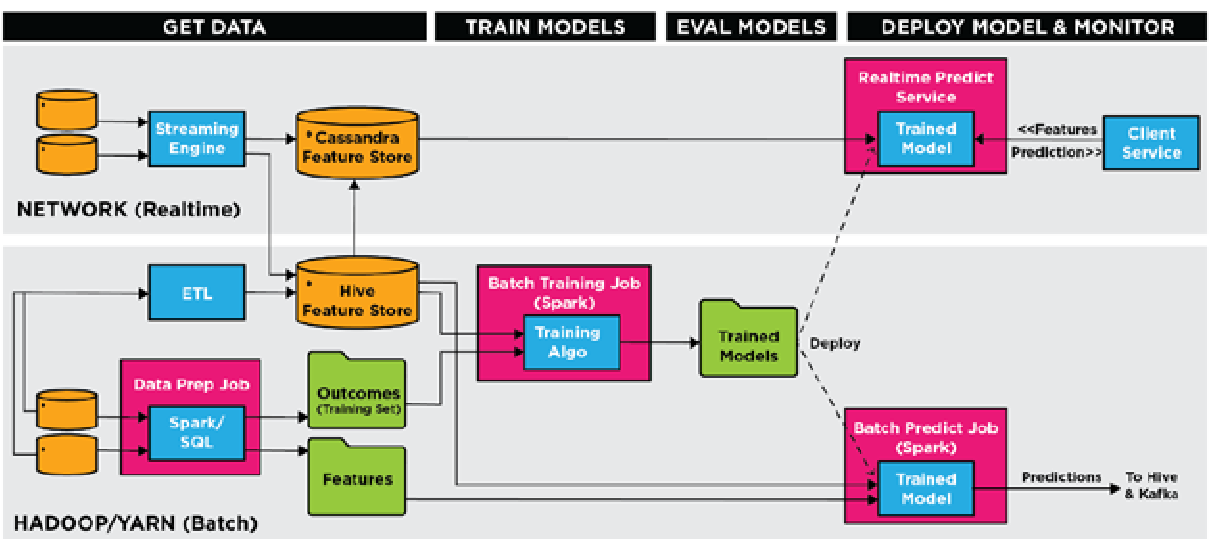


Figure 6-10. Smart Columbus Operating System Machine Learning Pipeline

Source: City of Columbus

The predictive availability model REST API[58] returns each parking zone where a prediction is available and a corresponding number, which represents the prediction of available parking. For example, a value of 0.70 would mean that it is 70% likely that a parking spot would be available in the corresponding zone. The code for the model is open source and available on Github:

- The Parking Prediction Model[59]
- The Parking Prediction Model Data Transformation[60] (The code used to convert the data sources from one format to another)

DIVISION OF INFRASTRUCTURE MANAGEMENT EMPLOYEE ALLOCATION DASHBOARD

Columbus' Division of Infrastructure Management has four outposts. Each outpost produces a work order task and employee hour allocation report at a cost of one man-hour per outpost. The lead supervisor then spends an additional man-hour collating and distributing the final report to the department Director. It is estimated that this dashboard will save the division up to 30 man-hours per week.

[58] https://parking.smartcolumbusos.com/api/v1/predictions

[59] https://github.com/Datastillery/parking_prediction

[60] https://github.com/Datastillery/parking_prediction_orchestration

Figure 6-11 shows a screen capture of the dashboard, indicating employee hours allocated to “plan” work, and responses to requests to the City’s 311 hotline for non-emergency City services (potholes, leaking fire hydrants, etc.) Current workload is compared to workload for a similar day the previous year.

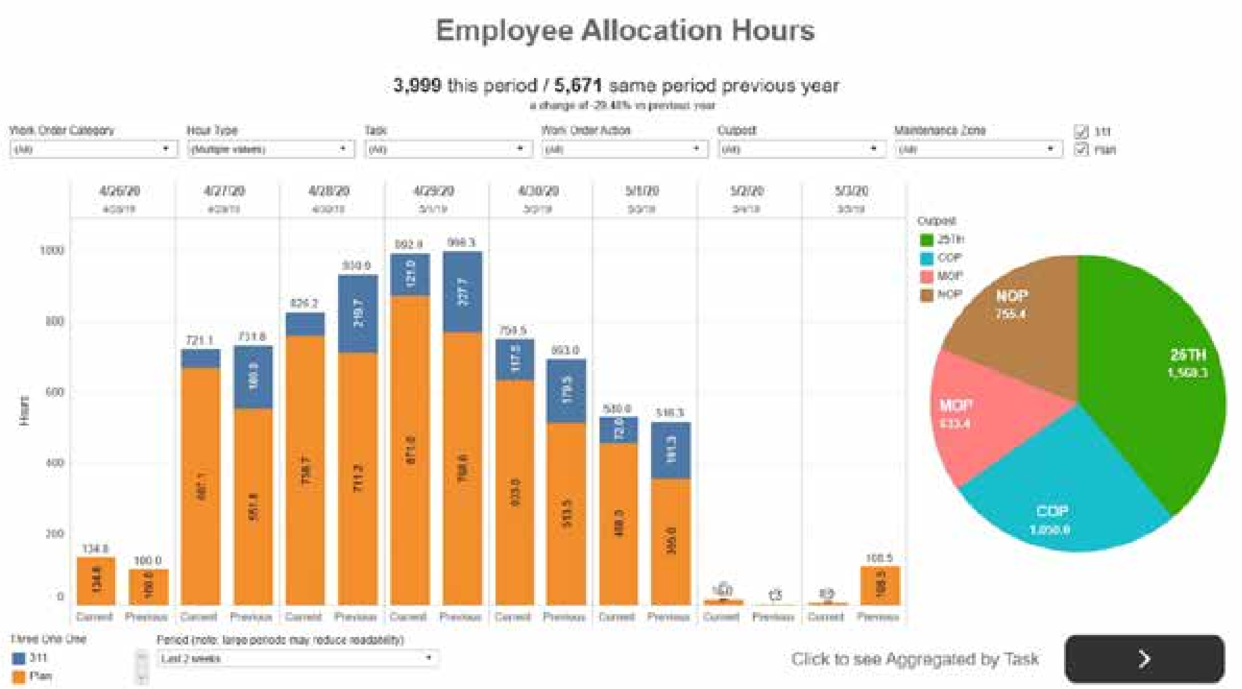


Figure 6-11: The Division of Infrastructure Management Dashboard

Source: City of Columbus

PROJECT DATA VISUALIZATIONS

The OS supported the other projects’ management teams by providing both the capability to query and visualize the CVE, MMTPA, and EPM data, as well as the knowledge transfer provided by the OS development team to understand how to produce the data-driven analytics displayed in their respective project chapters.

Figure 6-12 shows a screen capture of monthly distance traveled using the MMTPA project (as described in **Chapter 8**) data as queried and visualized via the OS. The time range is from September 2019 through April 2021. As with the OS, the MMTPA project will continue past March 2021, allowing for this data and visualization capability to continue after the end of the program.

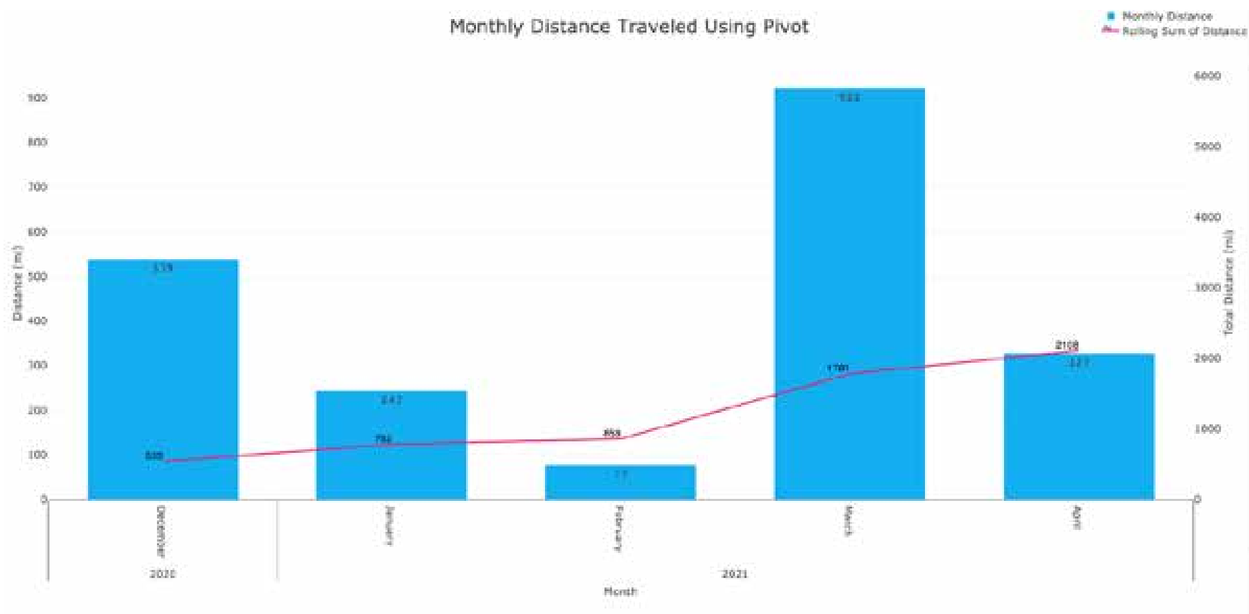


Figure 6-12: Monthly Distance Traveled Using The Multimodal Trip Planning Application

Source: City of Columbus, https://discovery.smartcolumbusos.com/visualization/8pnkn0kl

Figure 6-13 shows an output of the OS's analytic visualization capability whereby Basic Safety Message (BSM) data on the OS were queried to determine a vehicle's speed two seconds after it received an Onboard Unit (OBU) generated Red Light Violation Warning (RLVW). Evaluation of RLVW response is part of the performance measurement analysis, documented in the Smart Columbus Performance Measures Results. The outputs indicate the location upstream of the stop bar versus the speed two seconds after the warning is issued. Each point is colored according to the change in speed of the vehicle two seconds after the warning is issued. As the color changes from yellow to green, vehicle speed increases from 0 to 10+ mph, while as the color changes from yellow to red, vehicle speed decreases from 0 to 10+ mph. The CVE project continues to collect and evaluate performance data.

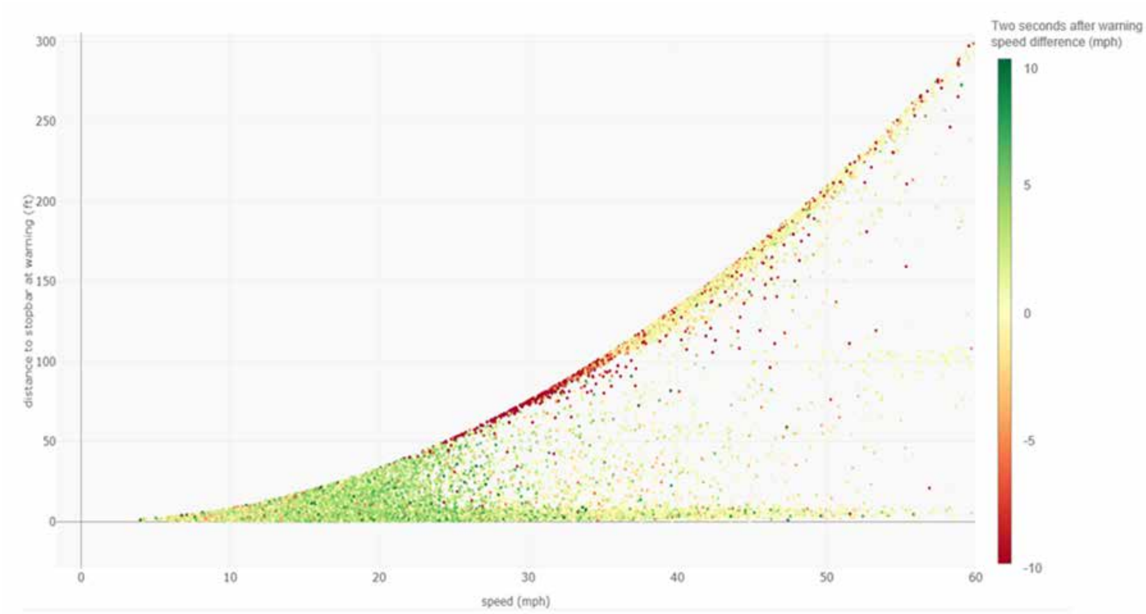


Figure 6-13: Red Light Violation Warning – Distance to Stopbar vs. Speed

Source: City of Columbus

Figure 6-14 shows a screen capture of Parking Meter Transactions by Payment Method for the EPM project (as described in **Chapter 12**).

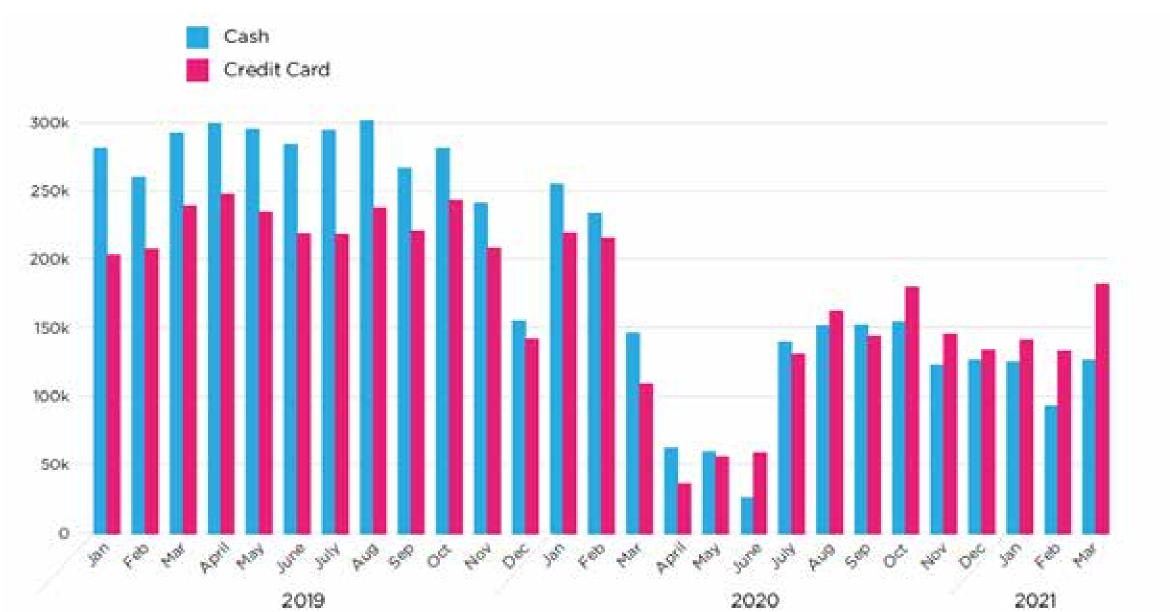


Figure 6-14: City of Columbus Parking Meter Transactions by Payment Method

Source: City of Columbus, https://discovery.smartcolumbusos.com/visualization/jnjtrj1t

6.2.3.3.3 Usage

During the demonstration phase, Google Analytics was used to monitor user behavior and performance of the system. These metrics were collected monthly and posted to the Smart Columbus Program SharePoint site, as well as routinely shared with stakeholders and USDOT.

The following data points were collected, and used to understand the use of the data, as well as inform which features of the OS could benefit from further testing and development:

- User Visits
- Visit Duration
- Page views
- Dataset Downloads
- Queries Created
- API Calls Made
- Popular Pages
- Visualizations Created

Table 6-2 shows the audience metrics recorded during the demonstration phase.

Table 12: Audience and Usage Data (March 2021)

Metric	Number
Public Datasets Ingested	2,018
Private Datasets Ingested	64
Users/Time	58,784
Pageviews/Time	193,980
Dataset Downloads	15,569
Dataset API Queries/Time	67,529
Most Downloaded Dataset	100 Year Flood Plain (Shape File) – 1,500 downloads
Second Most Downloaded Dataset	Connected Electric Autonomous Vehicle Route Segments – 330 downloads
Most Queried Dataset (Most API calls)	Short North Parking Sensor Sites March 2021 – 47,760 API calls
Second Most Queried Dataset (Most API calls)	Food Deserts data for the United States – 4,042 API calls

Source: City of Columbus

Figure 6-15 and **Figure 6-16** aggregate these metrics over time, demonstrating the steady increase in usage from January 2020 through March 2021.

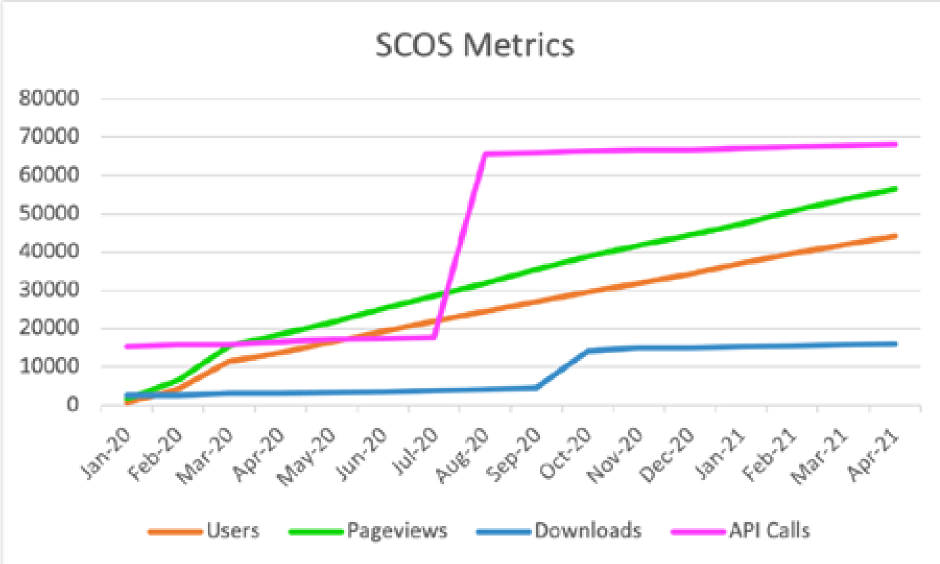


Figure 6-15. SCOS Metrics over Time

Source: City of Columbus

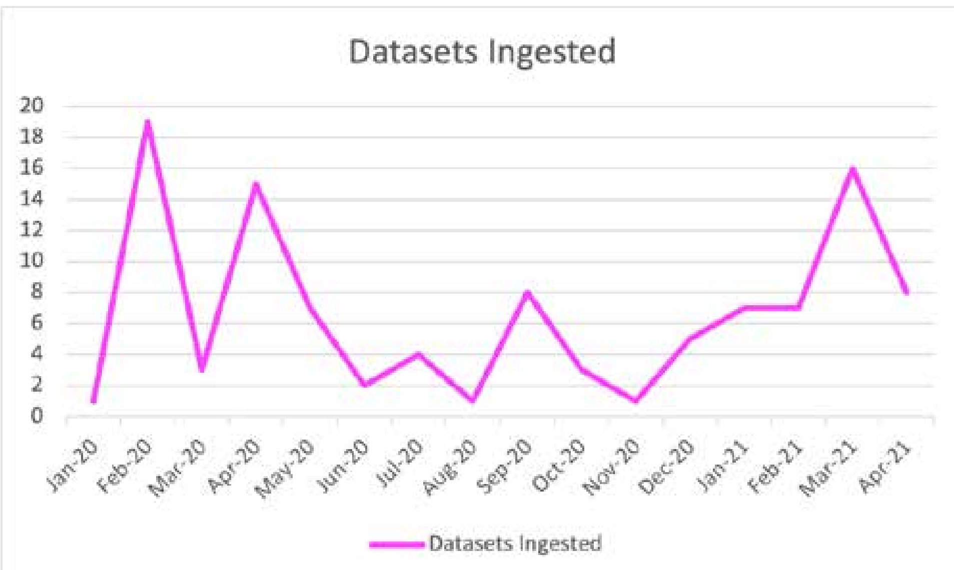


Figure 6-16. SCOS Datasets Ingested Over Time

Source: City of Columbus

6.2.3.3.4 Development Timeline

Figure 6-17 summarizes the OS's major activities. The project is anticipated to continue post-demonstration through January 2022. An Operations and Maintenance plan[61] was developed to be provide guidance for the continued operation of the OS.

[61] https://d2rfd3nxvhnf29.cloudfront.net/2020-06/SCC-B-SCOS-O%26M-Final-v1.pdf

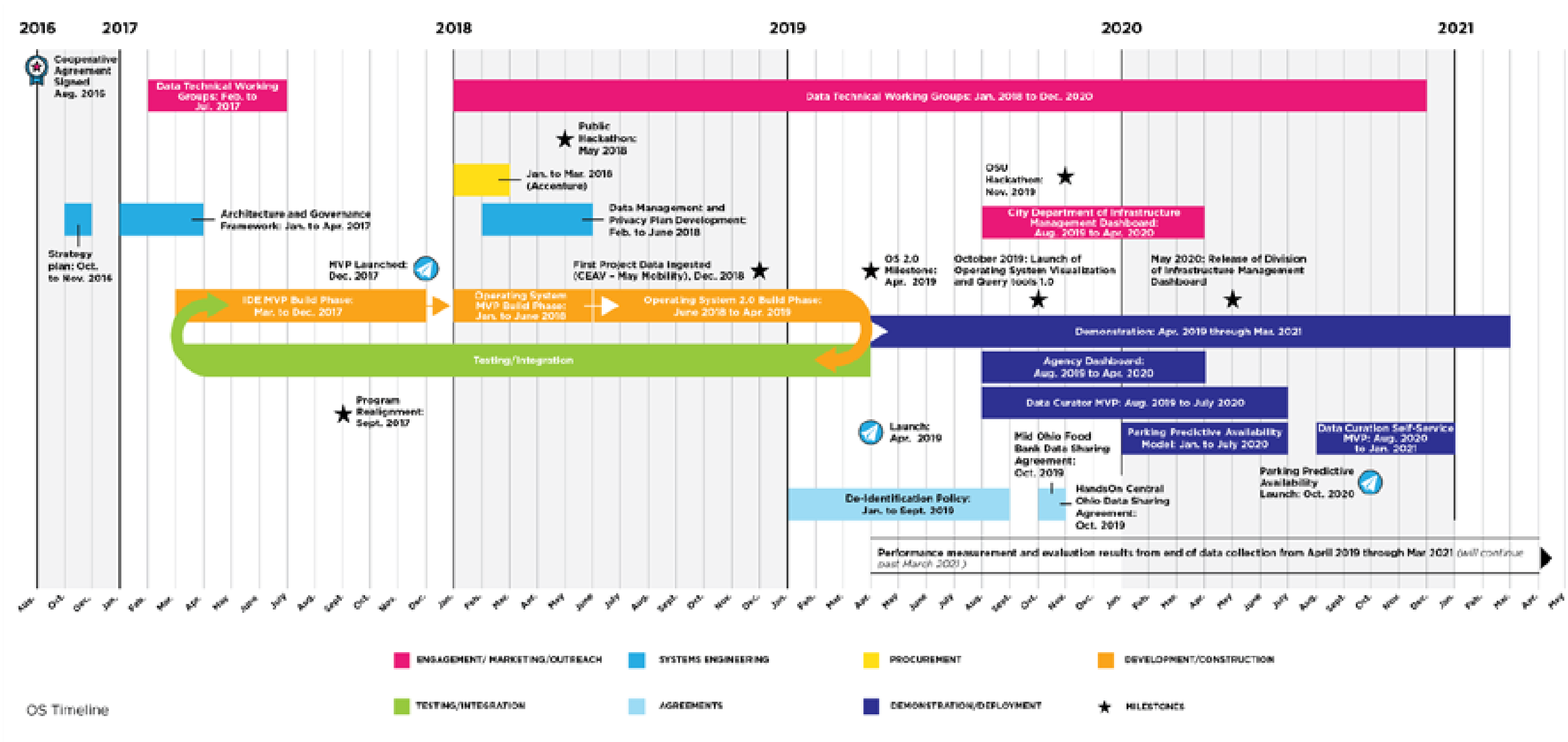


Figure 6-17: Smart Columbus Operating System Project Timeline

Source: City of Columbus

6.2.4. Communications

6.2.4.1. STRATEGIES

In January 2019, to manage general data and functionality requests that frequently came in via the platform's contact form, the OS project team developed a robust communication pipeline and response chain that included various leads of the project the Feedback, Review, and Oversight Group (FROG), for short) as depicted in **Figure 6-18**. The team used the Kanban application Trello to collect and prioritize the user feedback. This helped to triage requests to the correct contact and provide suitable response times to requests. All requests sent to the SCOS via this mechanism have been archived for future reference.

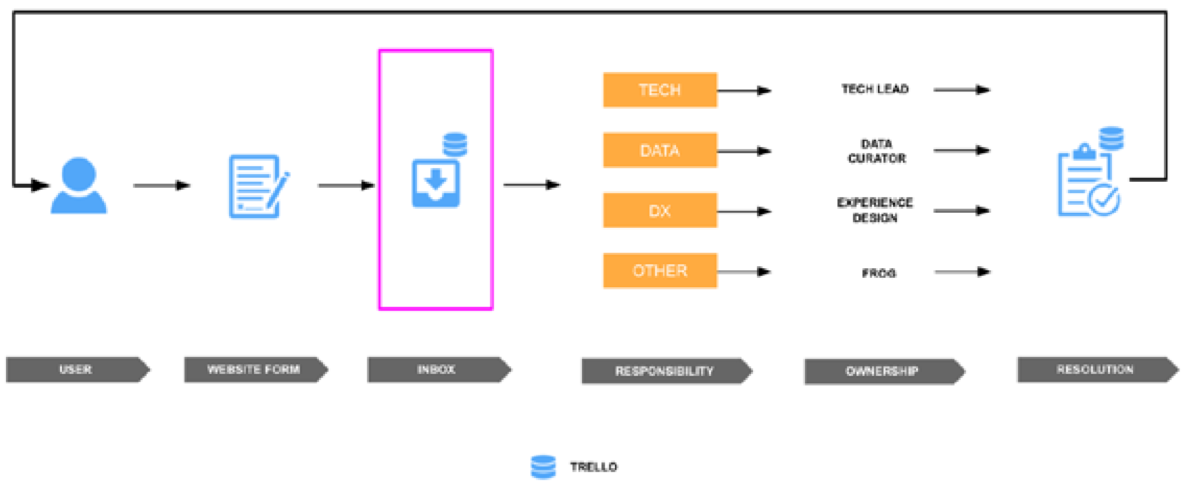


Figure 6-18: Smart Columbus Operating System User Feedback Workflow

Source: City of Columbus

As the platform launched, the project team wanted to advertise and highlight the key functionality that was developed for the SCOS, solicit user feedback, and promote both the project as well as upcoming and future OS functionality. This was coordinated by a variety of means, including:

- **Hackathons –** Two Hackathons in 2018 and 2019, promoted by The Columbus Partnership, as well as maintaining a presence at several data-enthusiast meetups and conferences. This benefitted the project by increasing awareness of the City's open data efforts, engaging more individuals and organizations with the OS, and encouraging use and feedback of the system features.
- **Smart Columbus Open Data Enthusiasts (SCODE)/Code For America groups' meetups –** Throughout much of the program, the delivery, product owner, and development team worked with SCODE/Code For America groups to host their monthly meetups at the Smart Columbus Experience Center. This usually began with an introduction by the SCOS product ownership team, allowing for communication of news about the OS, promotion of new features, and the solicitation of user feedback.

- **Data Technical Working Group (TWG) meetings – Chapter 3** provides an overview of all working groups that supported the program; the Data Technical Working group, however, was particularly critical to the OS. The engagement of the TWG varied over time, with the initial segments being very robust in terms of membership and level of collaboration. The first four TWG segments kept close contact via e-newsletters and public Slack (internet relay-chat-communication platform) channels. The impacts of the Data TWG are noted throughout the architecture and operation of the OS, as highlighted in the text box to the right.

In addition to these activities, there are additional tools that are being used for operations and performance measures:

- OS User feedback was collected through a survey found on the website.
- User feedback or questions from outside developers were posted on the Gitter public discussion forum, which was monitored by the OS team.
- Outside developers participated in the discussion forums and submitted online requests, including requests to upload open-source code and requests to collaborate with other developers in GitHub.

IMPACT OF THE DATA TWG

DATA

- Identified three new use cases, 22 new datasets – all of which were featured at the first Hackathon.
- Defined user personas and tied data to use cases

POLICY

- Drafted and reviewed Final DMP and DPP
- Recommendations on if and how to handle PII in the OS
- Researched and drafted 9 policies

DEVELOPMENT

- Guidance and research on OS licensing approach that was ultimately adopted
- Design plan for open source

ADOPTION

- Provided training that drove first community contributors to the OS

6.2.4.2. CHALLENGES

Despite engaging with potential users from many different segments of the community both public and private throughout the development of the OS, there are still challenges with changing behavior once the end product is built. In general, the challenges revolve around helping users and potential users understand how to use the tools that their user needs helped to create. This was quantified by assessing the overall interaction time for users who were accessing the Operating System. As other projects launched, the OS project team also continued engaging with the end users from these projects to build out visualizations. Through this process, it was also found that the best outcomes (defined in terms of value to the agency user) were found by working collaboratively with these users to define the purpose and outcome of the visualization. These challenges are summarized below and indicate that outreach remains a valuable tool even after a project/system launches to continually advertise the potential value of the system and engage with the user community on how to best leverage it.

- **User Adoption –** The project team struggled to publicize the value of the OS in meaningful ways. Quantitative traffic showed that many users interacted with the platform, yet only briefly, as indicated by the drop-offs as they traversed the site.

- **Agency Visualizations –** Getting agencies to adopt the platform to create visualizations took time. Outreach was required to build their trust, get access to and ingest, then transform their data. As was learned with the CVE visualizations, it was easier to create meaningful visualizations once the data had been ingested into the OS, and the team could work together with partners to understand how to query and represent the data visually.

6.2.4.3. STAKEHOLDERS

While the project team worked throughout the Cooperative Agreement to develop, deliver, operate and maintain the OS project, stakeholders played a critical role in the process. **Table 6-3** summarizes the specific stakeholders that were engaged, as there were many diverse groups that came together to make the project successful. This table serves to highlight their contributions by categorizing them into three areas to indicate when their participation was used:

- **Systems Engineering –** Stakeholders that were engaged to define the features of the OS, which includes participation on the Data TWG.
- **Development –** These organizations/groups contributed to the build-out of the project. For the OS, these are the stakeholders that were engaged for feedback or testing once a feature was developed.
- **Demonstration –** These organizations/groups were engaged to use the features or data in the OS for a specific purpose since launch.

Table 13: Project Stakeholders

Stakeholders	Systems Engineering	Development	Demonstration
Government			
USDOT	X		
City of Columbus Department of Public Service	X	X	X
City of Columbus Public Health	X		
ODOT	X	X	
Ohio Turnpike and Infrastructure Commission (OTIC)	X		
MORPC	X		X
City of Dublin	X		
Franklin County Engineer’s Office	X		
National Renewable Energy Laboratory (NREL)	X		
Private Entity			
Aderis Health	X		
Atlas Policy	X		
Amazon Web Services (AWS)	X	X	X
Awareability Technologies	X		
Blue Kick	X		
CAS	X		

Stakeholders	Systems Engineering	Development	Demonstration
Cardinal Health	X		
Centric Consulting	X		
Charter Communications	X		
Coldwell Banker King Thompson	X		
CoverMyMeds	X	X	
Discreet AF	X		
Geotab	X		
HMB	X		
Honda	X		
Idea Foundry	X		
JPMC	X		
Grange Insurance	X		
Marriott	X		
Maven Wave	X		
Mutually Human	X		
Nationwide	X		
NetJets	X		
Nikola	X		
OCLC	X		
Ohio Health	X		
RoundTower Technologies	X		
Tekainos, LLC	X		
Working Ontologist, LLC	X		
Mobility Provider			
Central Ohio Transit Authority	X	X	X
Advocates/Grassroots			
Columbus Collaboratory	X		
The Columbus Partnership	X		X
Smart Columbus Open Data Enthusiasts (SCODEs)			X
Code for America	X	X	
United Way	X		
Paul G. Allen Family Foundation	X		

Stakeholders	Systems Engineering	Development	Demonstration
Educational			
The Ohio State University	X	X	X
Data Providers/Use Cases			
Mid-Ohio Food Bank			X
Hands-on Central Ohio			X
Individuals			
Phil Norman	X		
Sharon Wilhelm	X		
Gus Frezoulis	X		
Vijay Yadav	X		

Source: City of Columbus

6.2.5. Project Costs

This section estimates the project costs for both the deployment and operations phase of the project. The deployment phase was from the beginning of the project to April 22, 2019 when version 2.0 launched. The operations phase was from the 2.0 launch to the end of the demonstration period, from April 23, 2019 to March 31, 2021. **Table 6-4** and the figures break out the costs of the project by phase and vendor.

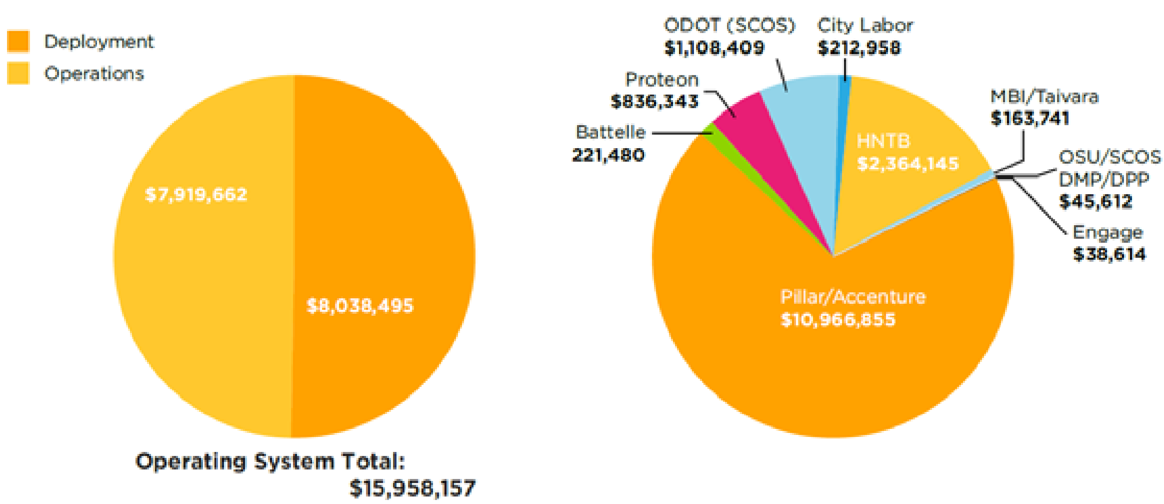


Table 14: Deployment and Operations Cost of Smart Columbus Operating System

OS Vendor Actuals	Deployment	Operations	Total
Pillar/Accenture (GAMMA Force, Unicon)	$4,434,328	$6,532,527	$10,966,855
Battelle	$94,147	$127,333	$221,480
Proteon	$755,843	$80,500	$836,343
ODOT	$550,596	$557,813	$1,108,409
OSU SCOS DMP/DPP	$34,209	$11,403	$45,612
City Labor	$165,030	$47,928	$212,958
HNTB (Tsibouris and Associates)	$1,961,628	$402,517	$2,364,145
MBI (Taivara)	$4,100	$159,641	163,741
Engage (MurphyEpson)	$38,614	-	$38,614
Total	**$8,038,495**	**$7,919,662**	**$15,958,157**

Source: City of Columbus

6.2.5.1. OPERATIONS AND MAINTENANCE COSTS

The Monthly Reoccurring and Support Costs table, from the Smart Columbus Operating System Operations and Maintenance Plan,[62] summarizes the materials costs (software and services) for the SCOS, as it will continue to operate post-demonstration. Certain services, such as the data curator staff, are not included in this estimate; during the Cooperative Agreement, data curation was provided by Battelle through an in-kind contribution. A data curator UI (as described earlier in this chapter) has automated this functionality.

All costs have been normalized to the monthly level. If a software, service, or other resource is not listed in **Table 6-5,** then there are no costs involved with using or accessing it.

Table 15: Monthly Reoccurring and Support Costs

Material/Software	Description	Monthly Costs
Amazon Web Services (hosting) EC2, SES, S3)	Ÿ Always-on production server Ÿ Development servers are enabled as needed and can be disabled after use Ÿ S3 storage for system backup Ÿ Costs vary on usage and a sample breakdown of cost can be found in Appendix F	~$12,000/month (includes all environments)
GitHub Repositories	Ÿ 12 private repository package(s)	$88/month

62 https://d2rfd3nxvhnf29.cloudfront.net/2020-06/SCC-B-SCOS-O%26M-Final-v1.pdf

Material/Software	Description	Monthly Costs
Akeeba	Ÿ Akeeba Backup PRO Ÿ Akeeba Release System	$4.68/month
ZenHub	Ÿ 12 users Ÿ Add-on for GitHub that supports issue management and tracking	$5.00/month
OpenVPN	Ÿ 12 users Ÿ Provides secure access to the development/testing environment	$15/month
Logman	Ÿ User and site analytics	$8.25/month
SP Page Builder	Ÿ Page builder for Joomla	$3.92/month

Source: City of Columbus

6.2.5.2. KEY LEVERAGED PARTNER CONTRIBUTIONS

Table 6-6 summarizes the key leveraged partner contributions to the SCOS during the demonstration. It captures the partner, an estimate of their contribution (as some were made through in-kind contributions or work that did not require invoice submittal/approval to the City), and a brief description of the work that was done.

Table 16: Summary of Contributions by Key Leveraged Partner

Partner	Estimated Amount	Description/Item
AWS	$1,000,000	Currently hosting OS
Battelle	$1,000,000	Development and data curation
The Columbus Partnership	Specific amount for OS not disclosed	Provided communications support for the OS, for example, outreach and engagement related to Hackathon events and working groups
INRIX	$1,424,000	Traffic data for Performance Measures

Source: City of Columbus

6.3. PROJECT EVOLUTION

6.3.1. Scope and Management

While the IDE project began its development and delivery process in 2016–2017, a number of programmatic changes were taking place in the program that would impact the trajectory for the OS. In early 2017, the City announced that its first Chief Innovation Officer would lead the oversight of the Smart Columbus Program. The change in the PMO structure and accompanying staff changes led to the complete re-evaluation of the program delivery methods and some key changes in the OS. The new delivery team included seasoned delivery specialists both within the PMO and with new consultants being brought on board in late 2017 and early to mid-2018.

Critical outcomes of this transition included an update to the visioning work to reset the vision for the OS as more than just a place to share and store data. The result was a reimagined IDE, one that played a more central role in the overall Smart Columbus Program. This ultimately led to the rebranding from IDE to the SCOS. In addition, with experienced product owners on board for both the City and consultant staff, the PMO assumed complete ownership of the development process, providing more engagement in the direction and delivery for the project and the Agile approach it followed.

6.3.2. Architecture

While the deployment approach for the OS project aligned closely with the approach laid out at the beginning of the program in terms of the application of the Agile methodology, technical changes were made along the way. The notable changes to the project architecture and design include:

- **Content Management –** The decision was made in October 2017 to transition from Wordpress to Joomla as the IDE's content management system, as it was determined that Joomla offered more functionality and flexibility. Joomla is a widely supported open-source tool that could be maintained easily by the project team. Joomla provided an integrated user experience for people to learn about the program, discover datasets, and download them for offline use.
- **Visualization Tools –** JupyterHub was selected as the visualization tool, as it was a popular standalone desktop application favored by data scientists to perform queries and visualize data. A web-based variant was installed and connected to the OS for public use. While a robust tool, iterative user testing revealed that the process of logging in to the online JupyterHub tool (separately from logging into the OS) and operating it in a web browser was time and resource intensive, providing a poor user experience.

  The OS development team, in conjunction with the Data Curator, evaluated several other visualization tools, including Kepler and Plotly. Plotly, an open-source web-based visualization tool was selected as since it was open source, it could be integrated as a feature within the source code for the OS, providing a seamless experience for the user. Plot.ly was ultimately integrated into the OS, and in addition to the querying capabilities that were built alongside, formed a powerful workspace with which to produce tailored queries and visualizations that were demonstrated by the CVE project (and as shown in various figures in **Chapter 7**).
- **Platform Architecture –** The OS MVP was originally intended only to store and share data, and was built using CKAN, an open-source software platform widely in use by other data portals. Upon evaluation of the program by the City, the product vision of the IDE was expanded to not only store and share data, but also integrate data with systems and projects. It was determined by the project technical and system architects that CKAN could not scale or support the system integrations and streaming data connections necessary (for example, COTA real-time streaming bus locations). Nor was CKAN scalable enough to handle the large data requirements for ingesting project data (such as the CVE streaming data).

  In the summer of 2018, the development team benchmarked and evaluated other platforms, such as Kylo[63] and Apache Hadoop.[64] While Kylo met the feature requirements (open-source data platform, streaming capabilities), the platform lacked maturity, and the sponsoring organization, TeraData, had limited support for implementation. Hadoop was an extensive application and determined to have features beyond what was necessary that could not be installed in a modular fashion.

[63] https://kylo.io/

[64] https://hadoop.apache.org/

A new system architecture was designed by the internal project team (the Elixir-based microservice architecture outlined at the beginning of this chapter) and approved by the ARB in late 2018. It was designed and built by the internal development team and relaunched in April 2019 as the Smart Columbus Operating System 2.0.

The MVP platform (CKAN) was removed in July 2019 after it was determined that all data had been migrated to the OS 2.0.

6.3.3. Personally Identifiable Information

As discussed in **Chapter 3**, the protection of PII was identified as an early priority in the program. When the DMP and DPP originally began development, it was envisioned that some PII would be collected and that protections would be required. As the PMO worked with subject matter experts through the Data TWG to develop these plans, the final versions published in 2019 reflect the overarching policy that PII, if collected as part of any other Smart Columbus project, would not be shared with the OS. This policy also applies to *any* dataset ingested into the OS: the OS does not collect or store any PII, including protected health information (PHI) and payment information (PCI). Much of the work of ensuring that data does not include any PII or other protected information falls to the data curators, who follow a strict de-identification policy.

Not hosting PII on the City-owned OS has the following benefits:

- Less privacy and security risk
- Reduced requirements in product and operations
- Strengthened public trust (eliminating PII from the OS protected the team from violating data privacy rules)

However, the following costs and missed opportunities are also associated with the OS not ingesting PII:

- **Less data in the OS –** If the OS were structured such that PII could be stored, then more datasets could have been ingested into the OS.
- **Fewer potential uses –** The PII restrictions meant that the OS had to drop three programs that were part of the original vision (the Common Payment System, the Trip Optimization Engine, and the Machine Learning Pipeline).
- **Fewer potential users –** Allowing PII data ingestion into the OS and adjusting the privacy policies could have enabled more agencies and private users to participate and use the OS as the primary data platform for exchange and analysis. It would also enable the OS to serve more use cases.
- **Missed marketplace opportunities –** Making the OS as a marketplace for purchasing and selling data could invite better public and private collaborations; however, purchasing and selling data is likely to have substantial data privacy and public trust consequences. Therefore, these actions must be considered very carefully and with appropriate consultation with privacy experts and the public.
- **Less functionality –** When the OS was restructured so that PII was not ingested or shared in the platform, it reduced the amount of risk relating to the OS, but also decreased the viability and usefulness of the OS as compared to the initial vision of the OS that contained PII. This restriction specifically meant that the following Smart Columbus Program elements could not be supported by the OS:
    - **Trip Optimization Engine –** This feature was removed from the OS project roadmap because OS could not host the Trip Optimization Engine data without introducing PII into the system.
    - **Machine Learning Pipeline –** The pipeline was put in place to support the Trip Optimization Engine, which was removed because it required PII. Because the Trip Optimization Engine was removed from the roadmap, the Machine Learning Pipeline was also removed.

- **Common Payment System –** This feature was removed from the OS project roadmap because the OS could not host the Common Payment System data without introducing PII (such as payment information) into the system.

6.3.3.1. CONSIDERATIONS FOR INCLUDING PERSONALLY IDENTIFIABLE INFORMATION IN AN OPERATING SYSTEM

Building features into the OS and operational capabilities to enable both a public data platform and storage of information containing PII would enable more use cases and would be worth considering. This could greatly increase the number of datasets able to be ingested into the system. This also reduces the amount of time needed by project data curators to review datasets for PII. Allowing PII data ingestion into the OS and adjusting the privacy policies would enable more agencies to participate and use OS as the primary data platform for exchange and analysis.

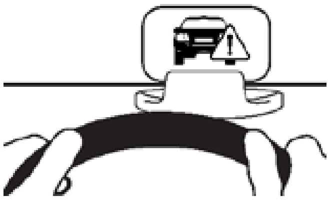
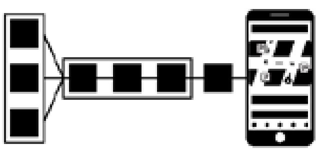
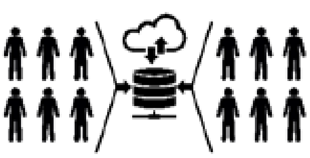
If PII were introduced, the full scope of Data Management and Privacy Plans would apply. Additional security policies and controls would also be required. Product and operational recommendations to consider include:

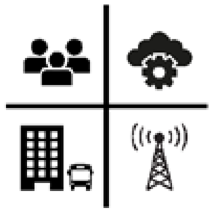
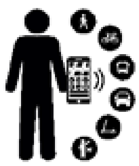
- Notifying individuals and receiving consent for use of PII
- Mechanisms for individuals to access and update their information
- Multifactor authentication required for access to PII
- Adjusting behavior from public by default to be more restrictive, which would reduce the risk of accidental disclosure
- Single Sign On (SSO) user authentication integration with external identity stores and strong Role Based Access Control access control procedures surrounding access to PII
- Log of access and disclosures
- Strong encryption would be required when moving data as well as storing data in the OS. Only key management would be allowed access.
- Considering multi-tenancy (where a single instance of software runs on a server and serves multiple tenants in the application), which allow systems to potentially leverage the security investment of the cloud vendor for mutual benefit of all tenants
- Ethical and legal implications as well as bias

6.4. CONCLUSIONS, LESSONS LEARNED AND RECOMMENDATIONS

The OS project addressed transportation challenges by deploying applications and strategies in the following USDOT's vision elements in **Table 6-7**.

Table 17. Smart Columbus Operating System Project Relationship to USDOT Vision Elements

VISION ELEMENT #3 Intelligent, Sensor-based Infrastructure 	The OS collaborated with the CVE project to ingest all messages received by roadside units in the CVE. Each Roadside Unit (RSU) listens to messages from vehicles within its range and reports them back to aggregators and from there to the OS. This data includes vehicle positions, signal states, signal priority requests, and more. In addition, one of the data sources for the EPM parking availability model is in-pavement sensors used by the City for on-street availability.
VISION ELEMENT #5 Urban Analytics 	The OS aggregates, queries, visualizes, and shares urban mobility data, such as MMTPA Data, and CVE data. In addition, the OS used EPM project data in conjunction with data from the City's Parking Services division to develop and implement the parking prediction model, which applied analytics and ML to three different parking-related datasets to predict future conditions related to on-street parking availability. The result is a direct demonstration of how analytics can be applied across sectors to create new and different applications.
VISION ELEMENT #7 Strategic Business Models and Partnering 	The OS was a project that successfully leveraged partnership opportunities. As an example, Amazon provided hosting services as in-kind contributions throughout the Cooperative Agreement. Similarly, Battelle provided data curation services for a majority of the award period.
VISION ELEMENT #9 Connected, Involved Citizens 	Connected residents generate, share, and use data and information in new and useful ways. The OS data is accessible to all online at smartcolumbusos.com and provided new features for visualization and analytics, which help users take and use the data to assist with problem solving. Performance measure survey results show an even split in terms of applying these tools to datasets generated by the program as well as those outside. In addition, survey result showed that this enhanced functionality was a draw in using the OS.

VISION ELEMENT #10 **Architecture and Standards** 	The OS architecture was developed and documented using USDOT's ARC-IT tool, with each architecture specifically built using the SET-IT program using three service packages from the tool with only minimal customization. With respect to this Vision Element, the OS architecture documents the system's interfaces to both other Smart Columbus projects and existing systems from the City and other stakeholders in the region, including mobility providers, MORPC and third parties and the information that is flowing between them and the agreements and institutional arrangements that are necessary for development, operations, and maintenance.
VISION ELEMENT #11 **Low Cost, Efficient, Secure, and Resilient Information and Communications Technology** 	Ÿ The OS is a replicable, scalable, sustainable data management platform that serves the needs of public agencies, researchers, and entrepreneurs. It has created the necessary software, storage and visualization systems to enable both the projects and other City departments (such as the Division of Infrastructure Management) to access, store and manipulate information. Ÿ While development was not particularly "low-cost," because the code and architecture documentation now exist and are available freely, replicating the OS in other cities should be relatively inexpensive. Ÿ The OS also demonstrates the criticality and priority of privacy and security. As discussed in **Chapter 3**, the protection of PII was identified as an early priority in the program, and from that point forward, affected the development of the DPP and the DMP and their implementation. The OS does not collect or store any PII, and as a program, the collection of PII was limited to performance measurement activities such as surveys and collected/protected it only for these purposes.

Source: City of Columbus

6.4.1. Conclusions

While there were architectural and structural challenges that were addressed early enough not to affect scheduled delivery of the project, the most significant hurdle for the OS was acquiring, ingesting, and demonstrating the effective use of data within the program. This stemmed from a number of challenges like process restrictions, such as not being able to ingest PII into the system as addressed earlier in the chapter, a lack of operational understanding that custom data connections would need to be created for each streaming data provider. However, the biggest barrier was the lack of data governance in the City. Many of the use cases were stalled by the lack of standardized, modern and accessible data. Data could be in third party software systems or stored on a desktop. Columbus is not alone – many governments across the country and world face this challenge.

The OS met each roadmap milestone on time, and by working with the other projects' management teams, the direction became clear regarding maximizing the effectiveness of the OS, with the parking prediction model and CVE reporting being two specific examples. Key conclusions are captured below with respect to the architecture and communications for the OS.

9. **System Architecture/Design for Scalability** – An extensible solution able to ingest large quantities of different data types was needed from the beginning, as it was known that some projects (such as CVE) would create a robust dataset. The OS can scale to handle large streams of data from multiple project sources. As an example, the streaming CVE datasets contain over 13 billion records, with an average file size of 21.3 gigabytes. Total CVE data is over two terabytes in size. This would not have been possible using the original MVP platform CKAN.

The elastic ability of the Smart Columbus OS allows resources to be added for short time use to handle high demands and then ramped back down to minimize ongoing costs.

The modular design of the OS microservices allows cities to only install what is needed. This makes implementation and operating costs variable. For example, a city may not need the security or frontend access modules, which then do not need to be installed.

The OS was also built with ease of replication in mind. This was done via cloud technology in a modular way, so that another city can implement the OS in a matter of weeks, reducing high subscription and development costs due to the open-source code.

10. **Streaming Data Connectors –** The key to being able to ingest multiple streaming data formats and sizes is less related to the platform built than the ability of the development team to create software "connectors." These connectors facilitate interfacing with multiple external systems by accessing their API and are what allows the OS to communicate with the EPM, CVE and COTA TVIER streaming data systems.

    a. **COTA TVIER –** Comprised of CVE messages that COTA buses receive as they move through the City. These messages are aggregated on the buses and loaded to a server and to the OS periodically.

    b. **CVE Data –** Comprised of all messages received by RSUs in the CVE. Each RSU listens to messages from vehicles within its range and reports them back to aggregators and from there to the OS. This data includes vehicle positions, signal states, signal priority requests, and more. It is ingested and available to project partners in near-real-time (data points are ingested 10x/second), and is used for research, analysis and reporting.

    c. **Open-Source –** Building an open-source platform allowed the team to build modularity into the system. This simplified adding or removing features as priorities or project needs change. This could improve adoption of the platform by other agencies, cities or governments by allowing them to install only what they need, when they need it, incurring minimal costs.

    d. **Cloud Agnostic –** The OS codebase does not rely on the architecture of any one cloud provider. It has been stood up successfully on the three major providers – AWS, Azure and Google. This should be attractive to agencies, cities or governments that may have existing agreements with a certain provider when considering the platform.

    e. **Replication –** Demonstrations have validated that with the available documentation and guidance provided by the development team on Github, the OS code can be set up and running by another city, agency or state in as little as two to four weeks by two developers *(source: Accenture).*

    f. **Visualizations –** The OS' visualization features allow the querying and display of any data within the platform, ultimately benefitting users and agency partners. In addition, a custom web connector[65] allows external querying of OS data in the commonly used visualization program, Tableau.

[65] https://data.smartcolumbusos.com/tableau/connector.html

Operating System Visualizations Bring Data to Life

As part of the Smart Mobility Hubs project, the City of Columbus ingested the CoGo bike-share data for all historical trips and updated the trips on a monthly basis throughout the deployment. This data included the start and end time, the start and end station, the trip id, and the coordinates of the start and end of each trip. **"The access to the data enabled me, as the project manager, to monitor the usage of the mobility hubs, especially to see how travel patterns changed due to the pandemic. I was not only able to tabulate trips made to and from the mobility hubs, but I was able to create visualizations of those trip origin and destinations."** The visualization brings the information to life and allows others to picture how trips are made in Columbus beyond a table in a report. This type of analysis will be useful in the future for the City and other partners as they look to where bike-share stations could be deployed to meet the needs of the community.

Jeffrey J. Kupko, P.E., PTOE, Senior Associate, Assistant Program Manager, Emerging Technologies - Smart Communities, Michael Baker International

g. **Metrics –** Building metrics into the platform from the beginning allowed the project team to regularly communicate adoption and usage of the OS to the public, project managers and USDOT. These metrics also guided the iteration and prioritization of features throughout the life of the project. Examples include:

   i. Dataset Downloads (Individual)

   ii. Dataset Downloads (Total)

   iii. Dataset API Calls (Individual)

   iv. Dataset API Calls (Total)

   v. Total Number of Visualizations Produced by OS Users

   vi. Total Number of Freeform Queries Produced by OS Users

   vii. Most Popular Datasets

10. **Acceptance and widespread use takes time and is built on customer satisfaction.** The OS leveraged stakeholder engagement throughout the development process. Stakeholders and the tools by which they were engaged informed the datasets that were sought out for ingestion, the policies that governed the OS, the technical capabilities of the OS and the user stories that were built and deployed. The capabilities and engagement did entice users, with usage and satisfaction noted specifically for non-program datasets and the visualization and analytics. Highlights from performance measure results are shown in **Figure 6-19.**

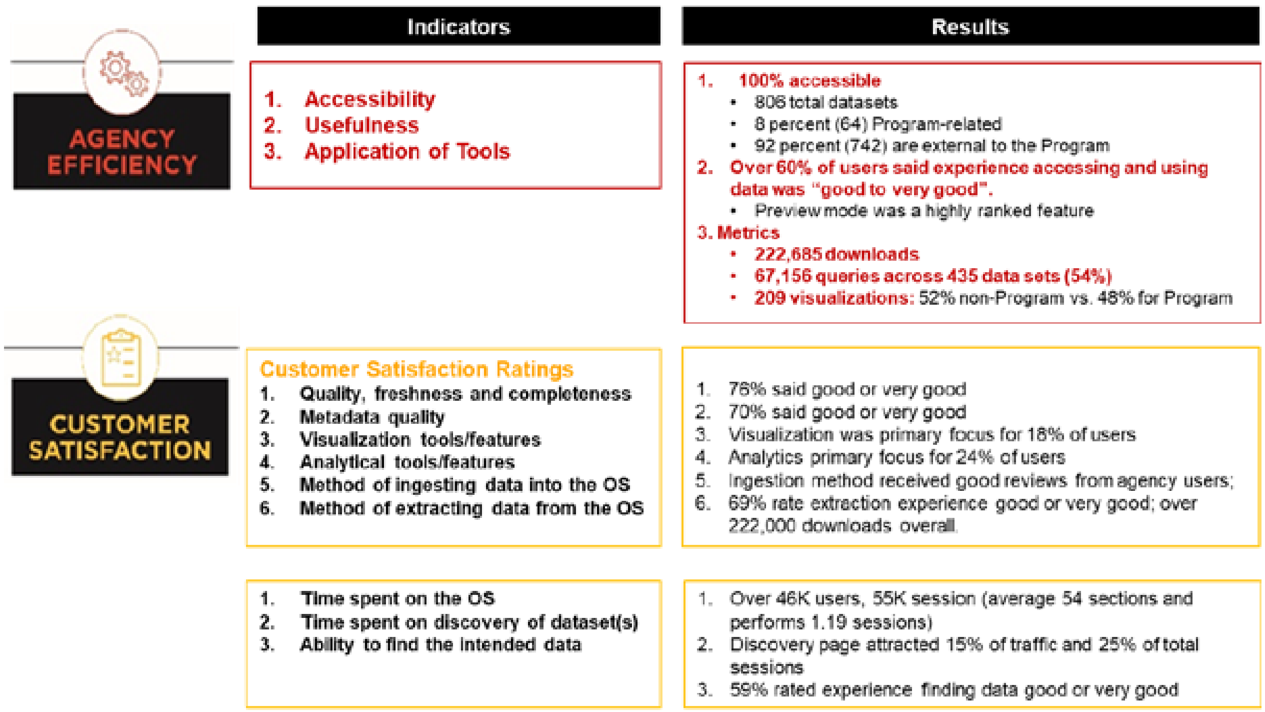


Figure 6-19. Evaluation of OS Data and Features between Program and Non-Program Uses

Source: City of Columbus

The engagement should continue to ensure that the full suite of capabilities is used for the benefit of all users. For the OS, it was found that the work of data scientists to demonstrate these tools, providing sample outputs of visualizations analytics resulted in increased interest and awareness for the potential benefits of not only the data but also the analysis tools. Engagement with users is important throughout the process and should not end once a project launches.

6.4.2. Lessons Learned

This section captures both sides of the project: what worked well and what could have been done differently. In the case of a complex data environment, there are an almost overwhelming set of options that impact functionality. This section also discusses the impact of decisions that were made around specific tools/functionality selected.

- **Development –** The Agile approach to developing and delivering the software to production should have been implemented earlier in the process. Incremental and iterative development allowed the team to deliver the OS in small increments. Delivery required iterating on the functionality, measuring the results, and improving upon what worked. The City began the initial development of the OS and was not accustomed to delivering projects in an Agile method. Although the project pivoted to Agile before development began, expanding the PMO to include a dedicated PM with a focus on technology to serve as the product owner for the OS and adding consultant staff allowed for a more robust Agile development team. Collectively, these changes facilitated faster, more efficient development, and delivered value sooner.

- **Scalability –** Considering the needs of other projects in their entirety from the beginning would have improved speed-to-market and saved development resources for other activities. CKAN was selected as the platform for the MVP as it appeared to satisfy the Cooperative Agreement requirements (the ability to ingest data, allow the public to download data, and being open source); however, when streaming data was determined to be a project requirement, it was determined that CKAN was not designed to support this, and the project platform needed revised using technologies that would support streaming data, such as Elixir (see Smart Columbus Operating System 2.0 outlined in **Section 6.2.1**).
- **APIs/ Connectors –** Greater focus on building in the ability to interface with a larger number of API types early on would have allowed the OS to ingest more and wider varieties of data over time. Initially, JavaScript Object Notation (JSON) and extensible markup language (XML) interfaces were prioritized based upon industry use; however, to be able to ingest streaming data from CVE, COTA Transit Vehicle Interaction Event Recording (TVIER) and EPM platforms, REST and simple object access protocol (SOAP) API connectors had to be prioritized and created.
  - **Geographic information systems (GIS), off-the-shelf products such as Esri –** Survey responses indicated greater consideration should have been given to develop a connector early on for Esri data tools. While this did not affect project or program data ingestion, the majority of city and state agencies that the City looked to adopt the OS platform are licensed with Esri tools and data formats.
- **Data Ingestion –** Prioritizing the creation of the Data Curator Self-Service Ingestion Interface earlier in the project would have allowed the data curators to take greater ownership of ingesting data. For the majority of the project, data ingestion required development resources to transform and ingest the data programmatically. After the curator UI was launched near the end of the project, developers spent less time ingesting data, and more time tending to Cooperative Agreement requirements and platform enhancements.
- **Datasets –** Increasing the variety of data ingested from other areas/organizations would bring more users to the OS.
- **Data Stewarding –** Building the ability to allow users to curate and steward datasets from their singular organizations would likely increase engagement with the OS, result in more datasets ingested, making more cohesive and complete datasets available.
- **PII –** Being able to store PII securely would have allowed more diverse business and use cases. While prohibiting PII storage in the OS made publishing data easier and reduced requirements for the platform, agencies mentioned that one of the limiting factors for not using the OS as a sole/primary source for data exchange is that not all datasets can be published due to PII and confidential data restrictions. Allowing PII data ingestion into the OS and adjusting the privacy policies would enable more agencies to participate and use OS as the primary data platform for exchange and analysis.
- **Building Awareness –** A recurring theme from surveyed agency partners was that there was not high awareness among their peers regarding the ability to find the agency data on the OS, which meant that data requests to the agency did not decrease. Once peers were alerted to the existence of the data within the OS, there were notable decreases in requests to the agency for said data.
- **Visualizations –** Agency surveys revealed the request for more information surrounding tutorials, education, and examples for less experienced users to be able to create visualizations using OS data. Feedback from agency surveys suggested that the interface was complex and intimidating.

6.4.3. Recommendations

For cities, agencies, or states that wish to understand how to increase the successful adoption of the OS within their own ecosystem, the following recommendations should prove useful:

- **Data –** Providing clear guidelines and documentation surrounding data formats, throughput and metadata to data dictionary providers will prevent resource-intensive rework.
  - **Formats Example –** COTA TVIER streaming data was provided in an incorrectly identified format. The data was ingested with that assumed format, which due to the size of the data took much time and involved large amounts of computing power. The format misidentification was discovered after the fact, subsequently the data had to be converted to the correct format and re-ingested.
  - **Throughput Example –** Unlike other streaming datasets ingested into the system (such as CVE streaming datasets) with normalized throughput, COTA TVIER data stream surges in volume depending upon the time of day. This creates auto-scaling of computing instances, increasing resource use that places strain on other parts of the system that were not designed for surges in advance. Consequently, additional work was performed to harden the resiliency of the system.
  - **Metadata and Data Dictionaries Example –** Many of the open datasets ingested into the system early on lacked complete metadata and dictionaries. Feedback from users indicated that this reduced the usefulness of the data. This required the data curator to audit the higher priority datasets to track down and complete these sections.
- **Data Types –** As mentioned previously, any city or state agency wishing to use the OS platform should prioritize building an Esri connection. This would likely increase interoperability and intra-agency data sharing.
- **Consider Use of PII –** As discussed in **Section 6.3.3**, there are both risks and benefits to including PII in an OS. Allowing PII to be ingested would enable more agencies to use the OS to store, share and analyze their data. In addition, making the OS a marketplace for purchasing and selling data could invite better public and private collaborations.
- **Development –** It is important to establish a high-performing Agile software development team, with a dedicated Project Management Professional (PMP) and Product Owner to implement projects of this scope and scale.
- **User Testing –** Getting feedback from users as feature iterations were released helped guide the UI design of the data platform, visualization workspace, querying tool, and data curation interface.
  - Key features were tested by:
    - The Division of Infrastructure Management, using the Employee Allocation Dashboard visualization tools
    - Data curators, for the data ingestion platform
    - Members of the SCODE group, using the data discovery platform
- **Delegate Data Stewarding –** Prioritize system development tasks to allow the assignment of users to curate their entire organization's inventory of datasets. This would likely increase engagement with the OS, as well as result in more cohesive and complete datasets.
- **Publicizing the OS –** Once an organization's datasets have been ingested into the OS, they should be encouraged to publicize the location of the data. This would drive their users to retrieve the data from the OS directly, rather than contacting the organization. This would increase OS usage and feedback, as well as help to improve agency efficiency by reducing the number of dataset requests they are asked to fulfill.

- **Visualizations –** Visualizing data, for example the CVE datasets, turned out to be a powerful storytelling tool. It took quite a bit of effort to train collaborators to be able to query the data in a useful way and create visualizations. It is recommended to make the interface easier to understand through the use of:
  - Video and written tutorials
  - Pre-populated example queries and visualizations with accompanying instructions to recreate.
  - Further customization and simplification of the UI, adding in-context help, information, and tooltips.
- **Community Involvement –** Involving the Columbus community of data enthusiasts, technologists, developers, academics, and entrepreneurs helped move the project forward, sparked curiosity, engagement, buzz, and made sure the problems that were being attacked were real and local. This was accomplished several ways:
  - The TWG was established to include representatives from the public, private, and academic sectors to pool and leverage their expertise during the strategy and planning phases of the project
  - The two Hackathons in 2018 and 2019, sponsored by The Columbus Partnership, brought together many multidisciplinary teams that used OS data to solve program-specific use cases, and produce viable proofs-of-concept, such as the SCODE group's "Community Services Locator" application.
  - Hosting monthly events at the Experience Center, as well as inviting the public to monthly OS demos allowed the project team to give updates on the progress made, features released, and plans for future enhancements and developments.

6.5. SUMMARY AND NEXT STEPS

The development of the OS has laid the groundwork for data-driven analytics that enable agency managers to understand how adjacent smart mobility projects – especially those that are continuing after the end of the Cooperative Agreement, like CVE and MMTPA – affect the City, as well as provide critical ML services to high profile apps like ParkColumbus.

The integration of infrastructure and mobility data into the OS will help optimize safety and efficiency. These efforts will continue as the OS continues to build out use cases related to improving event parking, traffic safety, operations, and management, especially as travel returns to pre-pandemic levels. The City has planned to continue operating and maintaining the OS for a period of 12-months following the conclusion of the Cooperative Agreement, including the analytical capabilities to drive certain functions for other projects that will also be sustained (namely, the predicted availability model for ParkColumbus). During this time, the OS will not only operate and maintain as currently designed, but also continue as-needed feature enhancements and updates.

In 2019, the City and The Columbus Partnership undertook an effort to understand the marketplace and value of the OS. The team explored the market including competitors and identified key features of leaders in the space. Ultimately, the clearest path to sustainability was to sell consulted services to support new instances of the OS. Neither organization was expecting to be a consultant and this path was tabled.

In May 2020, the City began a focused effort around planning for the sustainability of the OS. This included meeting with several other local governments to explore potential partnerships and opportunities that could leverage the OS. These include San Francisco Transportation Authority, the cities of Dublin and Worthington in Ohio, and the city of Louisville, KY. The two use cases that stood out as possibilities related to asset management and traffic management. Ultimately, the asset management use case would rely heavily on a speculative integration with Esri and has therefore been tabled but the traffic management use case requires additional exploration as it aligns with the national conversations around the merger of Traffic Systems Maintenance Operations (TSMO), Mobility on Demand (MOD) and Mobility as a Service (MaaS).

These conversations involve transforming Traffic Management Centers (TMC) into Transportation Operations Centers (TOC) – where TMCs are reactive and TOCs proactive.

The City also learned that the biggest barrier that big data projects face, is data curation. The OS as part of regional data governance model, could serve as the aggregator for key datasets that would allow data projects to create one connection to multiple data sources instead on multiple, disparate data connections. In both cases, the City and its partners need more time to explore the OS and its possibilities.

As a result of this need for additional time, the City is exploring two paths for near term support. The City is exploring simply paying to support the OS through January 2022 and the City has begun conversations with private entities to explore strategic partnerships and the potential for engagement on that front. This includes engaging with organizations that provide business and technology education services, strategy management, software services, and others.

Ultimately, the pandemic and constraints of the program did not allow the City to fully explore the value of the OS. It is anticipated that effort will continue to explore its value through January 2022 and the City will make a determination on the future of the OS on or before that time.

Chapter 7. Connected Vehicle Environment

7.1. PROJECT OVERVIEW

The goal of the Connected Vehicle Environment (CVE) project is to enhance safety and mobility for vehicle operators, both private and public, and to improve pedestrian safety in school zones. This was accomplished by deploying secure, high-speed wireless communication technology, and accompanying software applications, both on the roadside and in vehicles, to exchange critical situational data between the infrastructure and vehicles, and between individual vehicles. This data is then used to alert drivers of potential safety issues. Smart Columbus collaborated with public agencies and private companies to also support improved mobility for public safety, transit, and freight vehicles. Finally, the CVE serves as a source of high-quality data for traffic management, safety analyses and other transportation-related research purposes.

7.1.1. Infrastructure

The project is enabled by a communications network that allows the CVE to connect the region's signalized intersections using a secure, high-speed, fiber network backbone called the Columbus Traffic Signal System (CTSS). Roadside units (RSUs), which are used to broadcast the current state of a traffic signal or school zone, were then installed at 85 signalized intersections along four distinct corridors, as shown on the map in **Figure 7-1**. Intersections equipped include those operated and maintained by the City of Columbus, the Village of Obetz, the Franklin County Engineer's Office, and Ohio Department of Transportation (ODOT).

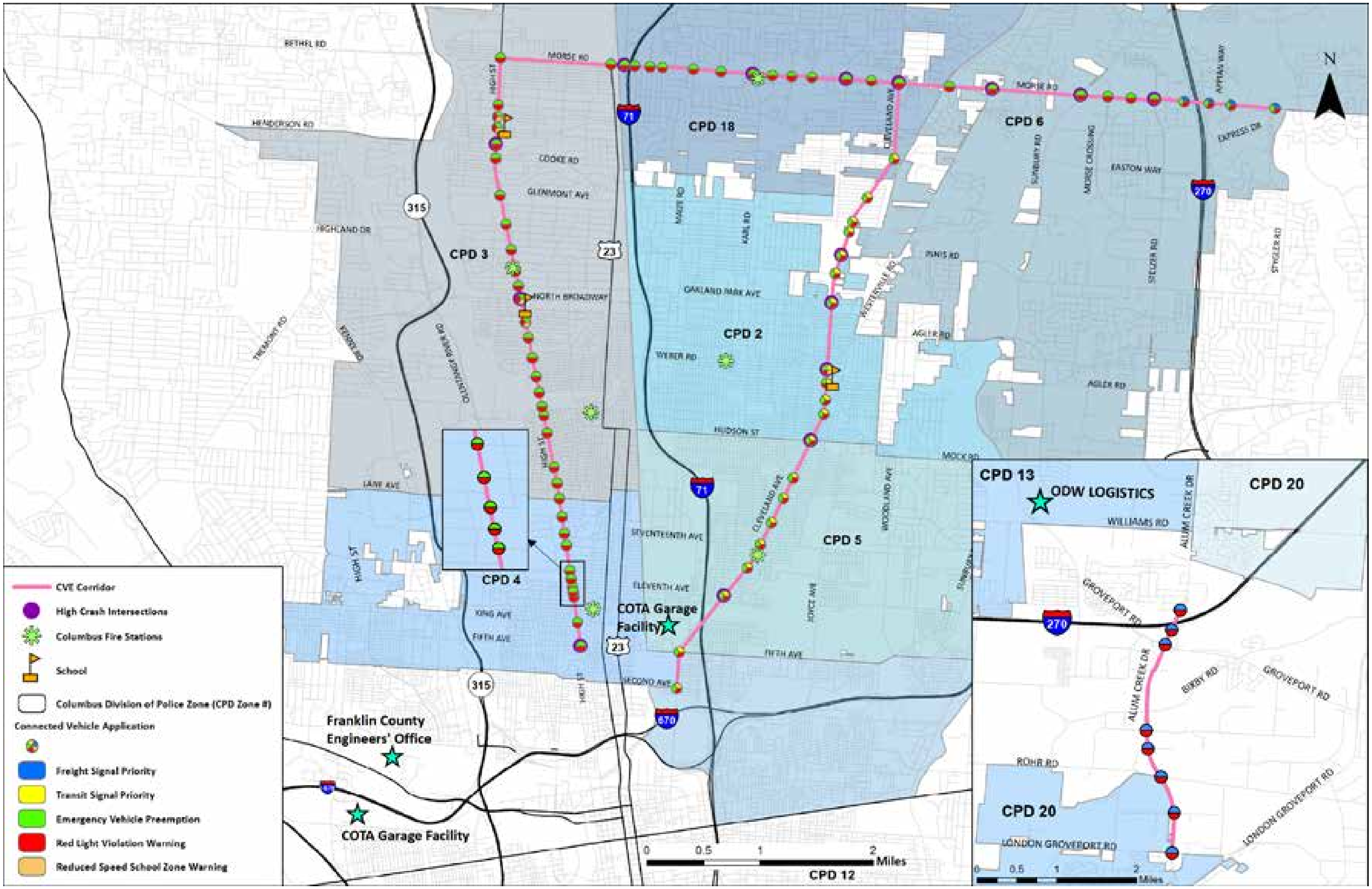


Figure 7-1: Roadside Unit Deployment Locations

Source: City of Columbus

7.1.2. In-Vehicle

Onboard units (OBUs), which receive and report critical warnings from the CVE infrastructure and other CV-equipped vehicles, were installed in over 1,000 vehicles. The ownership and vehicle class of these participants are shown in **Figure 7-2.**

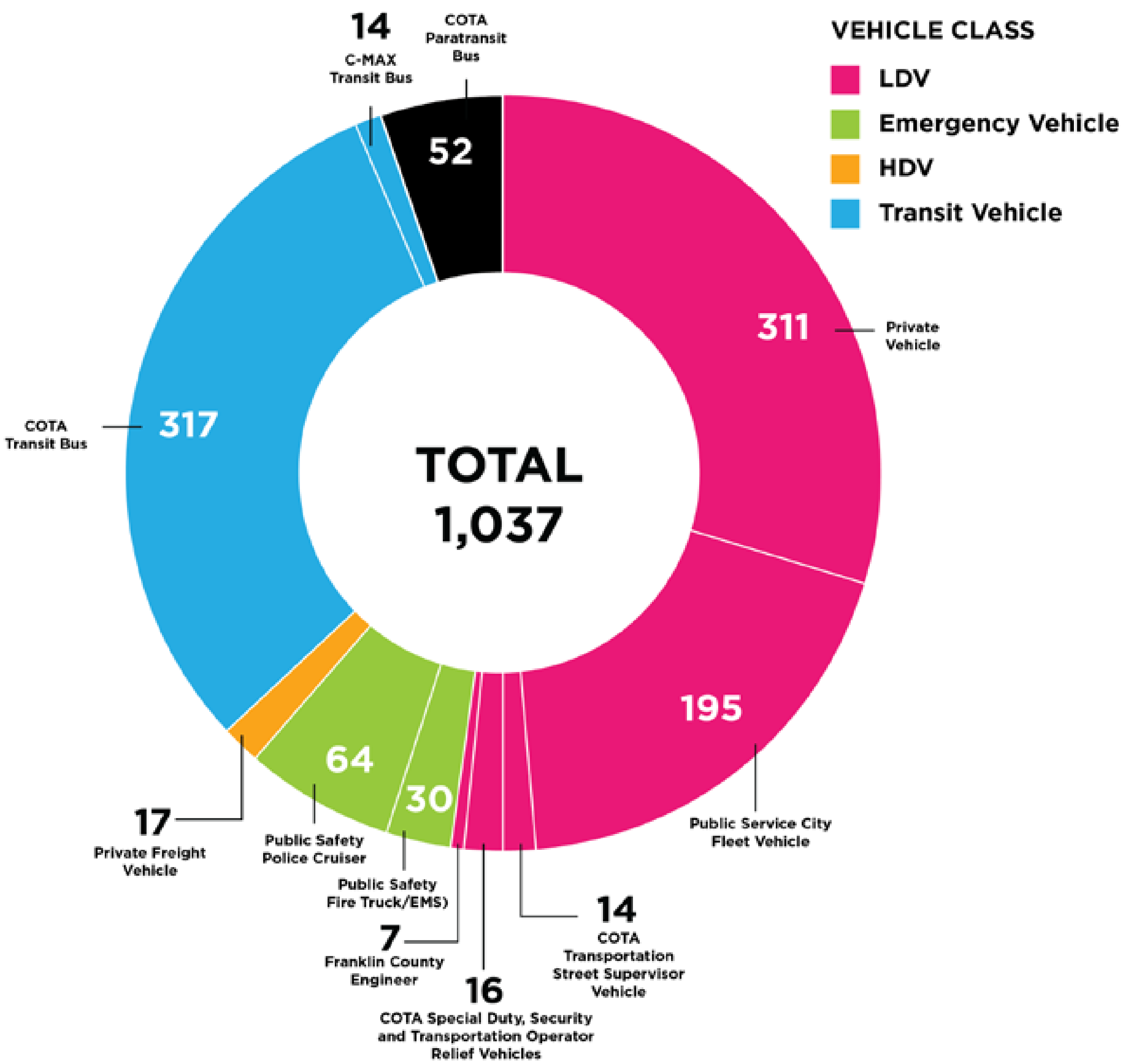


Figure 7-2: Onboard Unit Installation by Participants Count and Vehicle Class

Source: City of Columbus

7.1.2.1. CONNECTED VEHICLE APPLICATIONS

As shown in **Table 7-1**, 11 CV applications (including safety alert features, traffic priority signals, and data collection) were deployed in various combinations, depending on vehicle class. These applications supported both vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) interactions.

The majority of vehicle installations included a heads-up display (HUD), which afforded drivers the most complete set of applications, including the six application alerts shown in **Figure 7-3**.

Table 18: Connected Vehicle Applications and Vehicle Classes for Smart Columbus Connected Vehicle Environment

Class	Application Name	Vehicle OBU Class			
		LDVs	Emergency Vehicle	HDVs	Transit Vehicle
V2V Safety	Emergency Electronic Brake Light Warning (EEBL)				
	Forward Collision Warning (FCW)				
	Intersection Movement Assist (IMA)				
	Blind Spot Warning (BSW)/Lane Change Warning (LCW)				
V2I Mobility	Transit Signal Priority (TSP)*				
	Freight Signal Priority (FSP)*				
	Emergency Vehicle Preemption (EVP)*				
	Vehicle Data for Traffic Operations (VDTO)				
	Transit Vehicle Interaction Event Recording				
V2I Safety	Red Light Violation Warning (RLVW)				
	Reduce Speed School Zone (RSSZ)				

Source: City of Columbus
**Applications require deployment of both the roadside unit (RSU) and the onboard unit (OBU).*

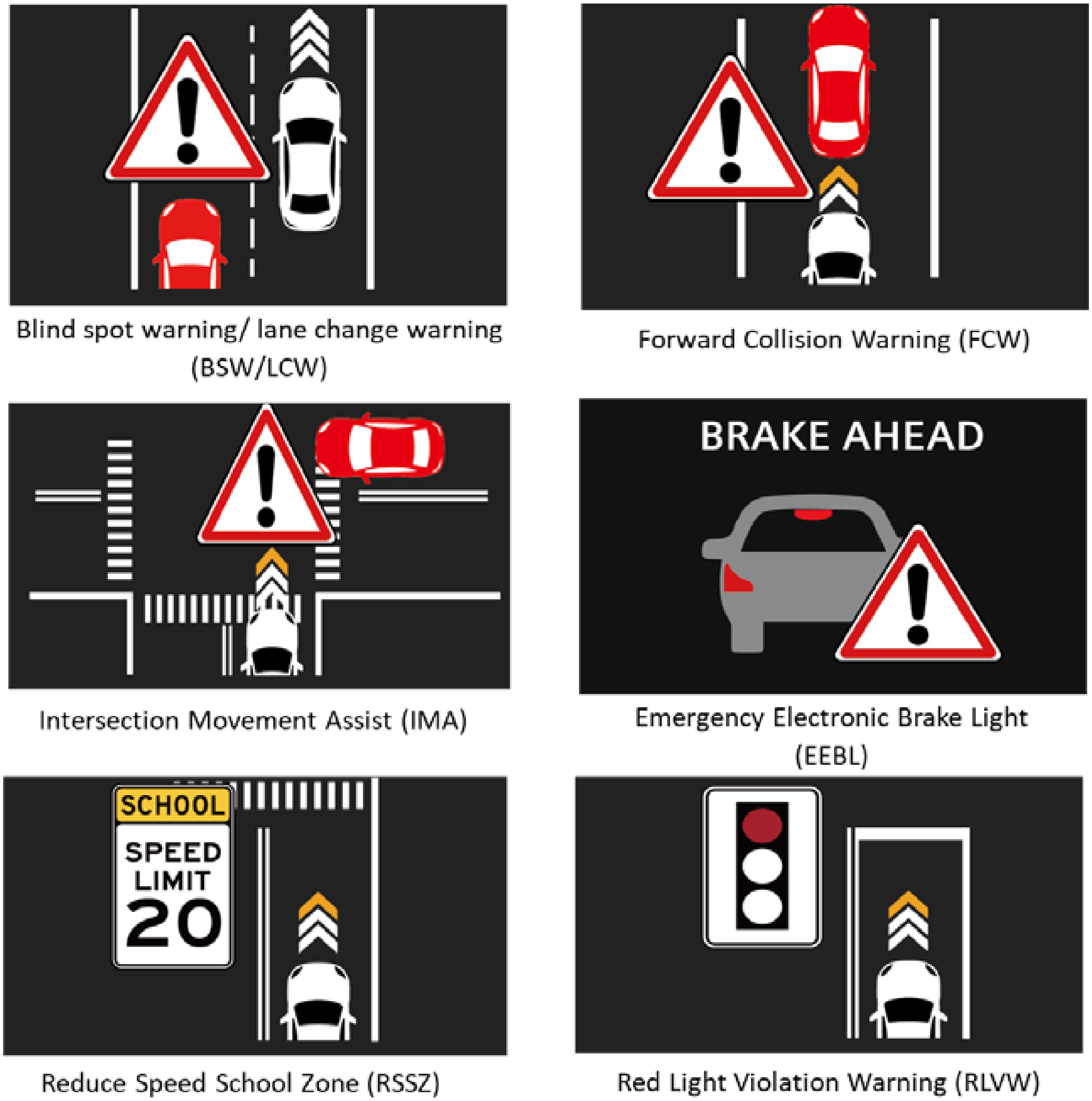


Figure 7-3: Connected Vehicle Application Alerts

Source: Siemens/WNC

7.1.3. Timeline

The timeline for the CVE project, similar to many Smart Columbus projects, commenced with the signing of the Cooperative Agreement in August of 2016 and continued through March 2021.

Figure 7-4 shows the major phases that comprised the CVE project.

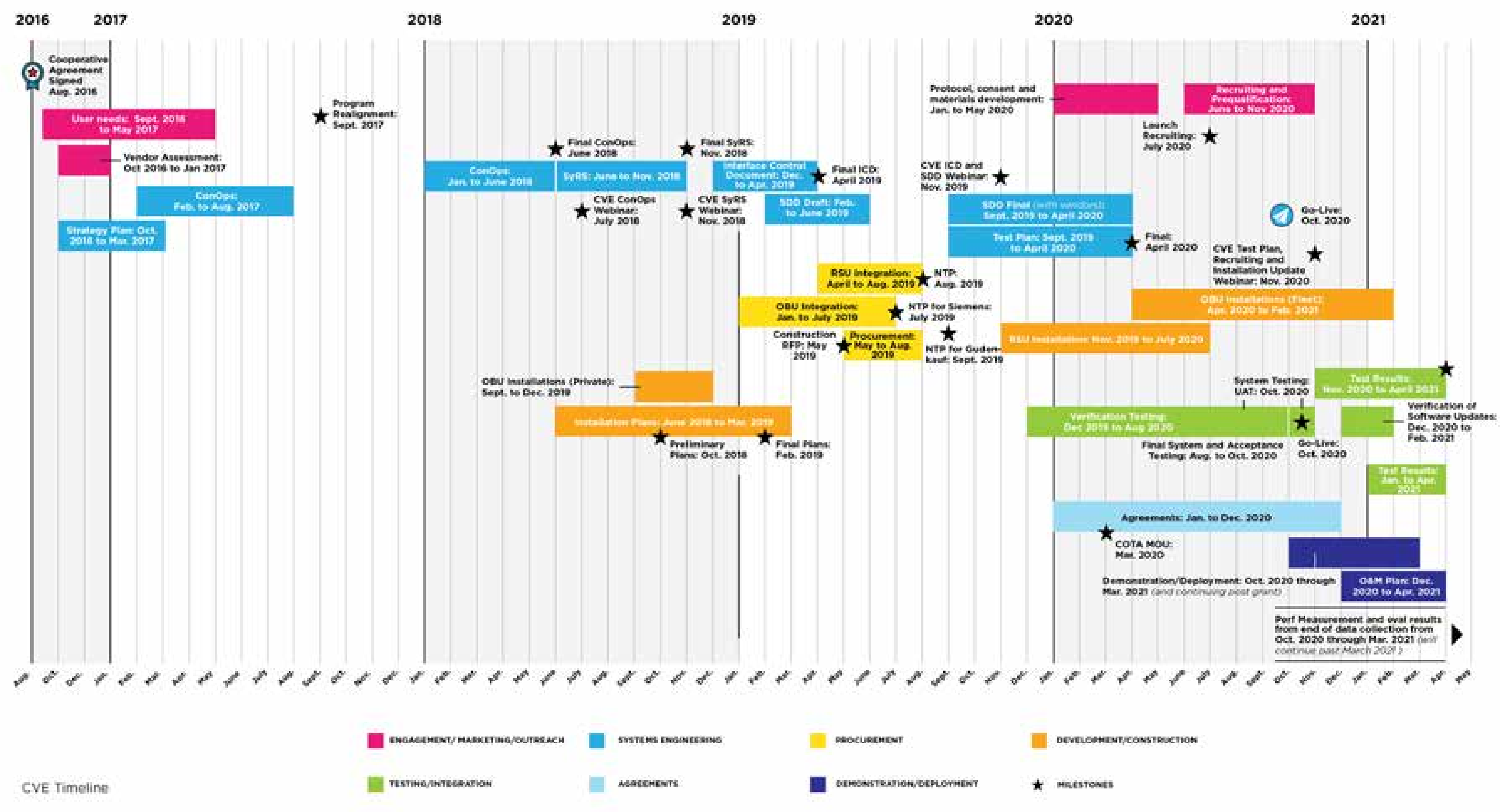


Figure 7-4: Connected Vehicle Environment Project Timeline

Source: City of Columbus

7.2. DEPLOYMENT SUMMARY

7.2.1. Systems Engineering Approach

As the winner of the Smart City Challenge (SCC), the City of Columbus was able to leverage the work products and outcomes of the three U.S. Department of Transportation (USDOT) connected vehicle (CV) pilot programs in New York City, Tampa and Wyoming[66] that were also supporting deployment of V2X[67] applications. Based on the existing body of knowledge from the CV Pilots, it was determined that the CVE project should be developed using a traditional systems engineering V-Model approach[68], as described in **Chapter 2**. The physical aspects of the project, such as the installation of the infrastructure and in-vehicle equipment, calls for a linear approach to project planning and management, which is an ideal V-Model situation. Through this method, the City was able to leverage lessons learned from the CV Pilots and contribute to the expansion of CV knowledge for future users.

In the early stages of the CVE project, the City engaged with many local, regional and statewide stakeholders, as well as USDOT, to develop the user needs for the Concept of Operations (ConOps). These user needs provided the foundation for the development of several other systems engineering documents, which were used during procurement for equipment vendors. These documents provided guidance for the system requirements that the equipment needed to satisfy, as well as the testing procedures that needed to be fulfilled prior to public launch. The team employed the use of a commercial requirements management tool to capture the relationships between user needs (as defined in the ConOps), system requirements (as defined in the system requirement specification) and test cases (and identified in the test plan). Establishing and maintaining traceability from user needs through requirements and specifications allows technical staff to readily identify gaps, allowing for additional design elements to be created as appropriate. In the reverse flow, test cases can be traced back to their root purpose.

7.2.2. Project Launch

Deployment of the CVE project was comprised of two parallel paths: the enabling of the system and the initiation of recruiting and private vehicle installation. In terms of the system launch, this was a rolling activity whose completion essentially aligned with the launch of the recruiting work. Specifically, as infrastructure was installed, energized and validated over time, it was left in the operational state, allowing fleet vehicles that were already equipped to have immediate benefits and interactions with the system. Private vehicle installation began in July 2020 with the beginning of private participant recruiting, which is discussed in **Section 7.2.4.5.2**. When the last RSU was enabled, launch occurred. As such, when private vehicle installation commenced, equipped vehicles could then immediately interact in the environment.

7.2.3. Demonstration

Following the installation and integration of the RSU equipment and start of OBU installations, the project launched in October 2020 and entered the demonstration period. The demonstration period for the CVE project is characterized by four major activities:

11. **Infrastructure Operations –** Monitoring of the infrastructure elements of the system, including all RSU, message hubs, and the network upon which they reside, to ensure proper operation.

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[66] *https://www.its.dot.gov/pilots/index.htm*

[67] *Vehicle-to-everything (V2X) includes V2V, V2I and other connections such as vehicle-to-device.*

[68] *Systems engineering concepts are described in **Chapter 2** of this Final Report document.*

12. **Vehicle Activity –** Connecting the vehicles with onboard equipment as they traverse the active corridors.
13. **Participant Engagement and Support –** Continued expansion in the number of CV-equipped vehicles as additional public and private participants continue to be outfitted with CV technology; and management of participants, including distribution and collection of performance measurement surveys, and managing questions, comments and feedback on the equipment as needed.
14. **Data Capture and Analysis –** Ingest, analyze and visualize data produced by the CVE project, supporting both specific performance measures outlined for this project as well as other insights that can be gained from the data.

7.2.3.1. INFRASTRUCTURE OPERATIONS

The City of Columbus uses the Kapsch Connected Mobility Control Center (CMCC) to regularly monitor the status of the CVE in accordance with the CVE Operations and Maintenance Plan. **Figure 7-5** reflects the operational status of the CVE.

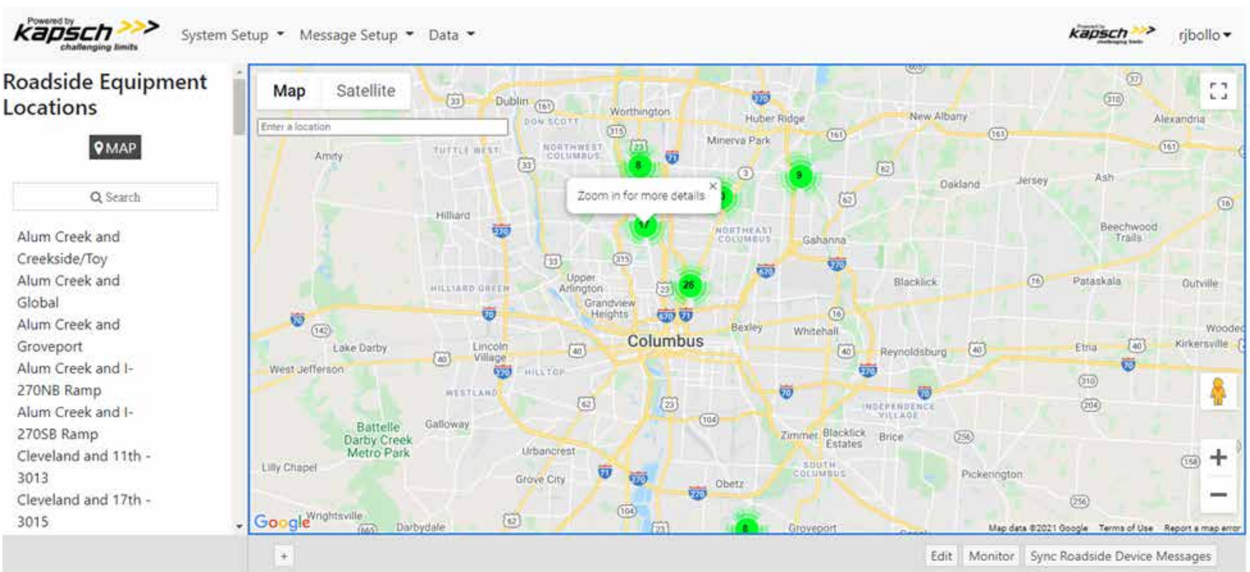


Figure 7-5: Monitoring Connected Vehicle Environment Infrastructure Operations

Source: Kapsch CMCC Software

Figure 7-6 shows RSU status for the period of March 1st – 21st, where green indicates a fully operational state. Orange and yellow indicate degraded performance or communication losses. This report helps determine if system-wide outage or individual device outages occur, and when they do occur. For examples, the two outages indicated on this figure where related to a planned system upgrade by the CMCC vendor, Kapsch, and the latter outage related to a loss in communications in the City network. A redundant fiber path has now been configured to prevent the communications loss in the future. The City of Columbus intends to continue to support the CVE after the demonstration period with both the RSU and OBU teams led by Kapsch TrafficCom North America and Siemens Mobility working under operations and maintenance contracts.

Figure 7-6: Connected Vehicle Environment Infrastructure Performance

Source: City of Columbus

7.2.3.2. VEHICLE ACTIVITY

With the completion of installation, over 1,000 CV-enabled vehicles are now traversing the equipped corridors. Data from these corridors are being captured at the rate of roughly 65,000,000 records per day. Basic safety messages (BSMs) produced by the equipped vehicles, and captured by the infrastructure, reflect a high level of activity along the equipped corridors – validating the recruitment strategy and supporting the desired performance measures and other analysis outcomes. **Figure 7-7** shows a heat map representing the activity of BSM data captured along a portion of the CVE.

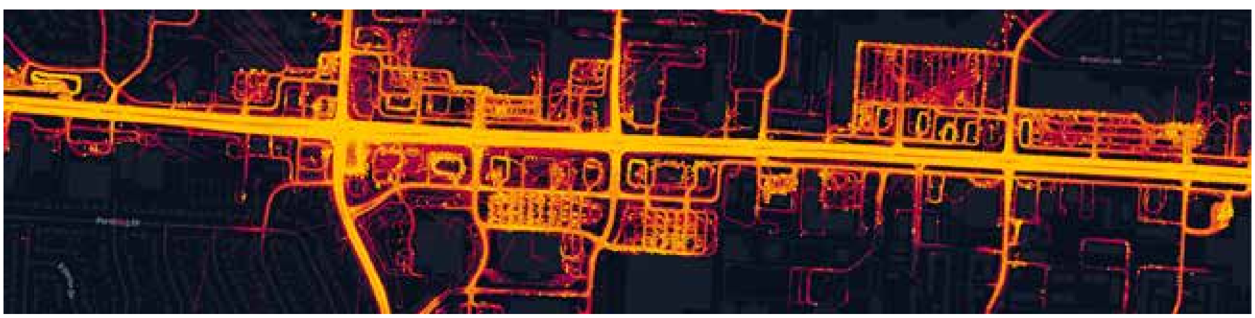


Figure 7-7: Connected Vehicle Environment Vehicle Interactions

Source: City of Columbus

7.2.3.3. PARTICIPANT ENGAGEMENT AND SUPPORT

The Smart Columbus team engaged with CVE project participants throughout the demonstration, for continued equipment support and participant surveys. Equipment support includes both troubleshooting and repair/replacement, or if the participant prefers, equipment removal (within the demonstration timeframe, which ended March 31, 2021). **Table 7-2** quantifies the different support activities that have occurred in relationship to the number of installations.

Table 19: Connected Vehicle Environment Post-Installation Participant Equipment Support

Vehicle Class	Installed	Repaired/Replaced	Removed
Private – Light Duty	311	24	6
Fleet – Light Duty	232	4	N/A
Transit	383	8	N/A
Heavy Duty	17	N/A	N/A
Emergency	94	N/A	N/A

Source: City of Columbus

As noted earlier, both public-sector and private participants were part of the survey process. **Table 7-3** identifies the survey response rate by driver/vehicle class. As shown in **Table 7-3**, the return rate of survey responses for private participants is over 95%, a welcome outcome for the project. Full details of the survey, including results and impacts are included in the separate Performance Measures Results Report.

Table 20: Connected Vehicle Environment Participant Survey Responses

<table>
<tr><th>Driver/Vehicle Class</th><th>Distributed</th><th>Reponses</th><th>Response Rate</th></tr>
<tr><td>Private Driver</td><td>1. December 2020
2. March 2021</td><td>1. 310
2. 298</td><td>3. 99%
4. 96%</td></tr>
<tr><td>Freight Operator</td><td>March 2021</td><td>1</td><td>5%</td></tr>
<tr><td>City Light-Duty Driver</td><td rowspan="3">March 2021</td><td rowspan="3">67</td><td rowspan="3">29%</td></tr>
<tr><td>COTA Supervisor</td></tr>
<tr><td>Public Safety</td></tr>
</table>

Source: City of Columbus

7.2.3.4. DATA CAPTURE AND ANALYSIS

During the demonstration period, the Operating System (OS) served as a robust resource to capture, manage, and visualize all CVE project data. Post-demonstration, the OS will continue to serve in this role.

7.2.3.4.1 Data Capture Summary

As of the end of the demonstration period, nearly 9.5 billion records of raw data have been ingested into the OS. It is expected that the OS will continue to serve in this capacity beyound the demonstration period. **Table 7-4** shows the breakdown of captured messages, including daily averages and total over the entire demonstration period. Infrastructure-generated messages are dependent on reliable and continuous operation of the infrastructure, including the communications network. Vehicle-generated messages are depedent on vehicles being within communcations range of the infrastucture.

Table 21: Daily Average and Demonstration Period Total Connected Vehicle Environment Project Data by Message Type

Source	Message Type	Daily Average	Total
Infrastructure-Generated Messages	Signal Phase and Timing (SPaT)	50,961,796	7,593,307,636
	Map Data (MAP)	5,053,552	758,032,757
	Traveler Information Message (TIM)	289,181	39,039,384
Vehicle-Generated Messages	BSM	6,707,453	1,006,118,002
	Signal Request Message (SRM)	5,313	600,364
Totals[69]			9,397,098,143

Source: City of Columbus

7.2.3.4.2 Data Analysis Summary

The Smart Columbus Performance Measures Results Report captures several key performance metrics that were identified as goals for the CVE project and published separately. The Performance Measures Results are available on the Smart Columbus website.[70] Those findings are not repeated herein. However, in addition to the performance measures, multiple other data analyses and outcomes were possible from the rich set of data captured in the OS. That dataset, which includes every CV message received by an RSU – SPaT, geometric intersection description (MAP), BSMs, etc. – allows for a virtually unlimited number of ways to analyze the data. Position data, common timestamps, and many other values can be queried, analyzed, visualized and mapped for use by traffic engineering staff, transportation planners, transit planners, safety personnel and more. Following are a few example analyses outputs that were requested by various stakeholders.

- **Hard Braking –** Hard-braking events are defined by certain longitudinal acceleration thresholds, or by the presence of a braking event flag in the BSM. **Figure 7-8** shows an example heatmap of hard-braking events as captured at the intersection of Morse and Stelzer Roads, a high-traffic area along the corridor. These events occurred over the period from November 1, 2020 through March 31, 2021. The size of the arrow represents the duration of the deceleration (ranges from 0.1 to 2.5 seconds) and the color represents the rate of deceleration. The direction of the arrow represents the direction of vehicle travel.

[69] *Total includes period beginning 11/1/2020 for SPaT, MAP and BSM. Total for TIM includes period beginning 11/16/20 and SRM beginning 12/8/20. All counts end on 3/31/21.*

[70] *Document will be available under Program Plans at: https://smart.columbus.gov/programs/smart-city-demonstration*

Figure 7-8: Heat Map of Hard-Braking Events

Source: City of Columbus

7.2.3.5. RED-LIGHT RUNNING

Red-light running events are indicated when the longitudinal behaviors of a vehicle passing thru an intersection conflict with the signal phase and timing at same intersection. This analysis uses data from BSM, SPaT and MAP messages and compares vehicle location and infrastructure features with a common timestamp to make this determination.

Figure 7-9 shows a heatmap of a portion of the CVE where red-light running events have occurred. The darker the color, the greater the number of events. A total 7,637 red-light running events, over the course of the demonstration period, were identified.

Figure 7-9: Heat Map of Red-Light Running Events

Source: City of Columbus

7.2.3.6. APPROACH SPEEDS

Figure 7-10 represents a sample distribution of vehicle approach speeds, calculated from BSMs, for all approaches at a single equipped intersection for a period spanning all weekday hours. Features of OS allow for interested parties to quickly change inputs to specify which intersection, which hour of the day (or all hours), and weekday/weekend periods.

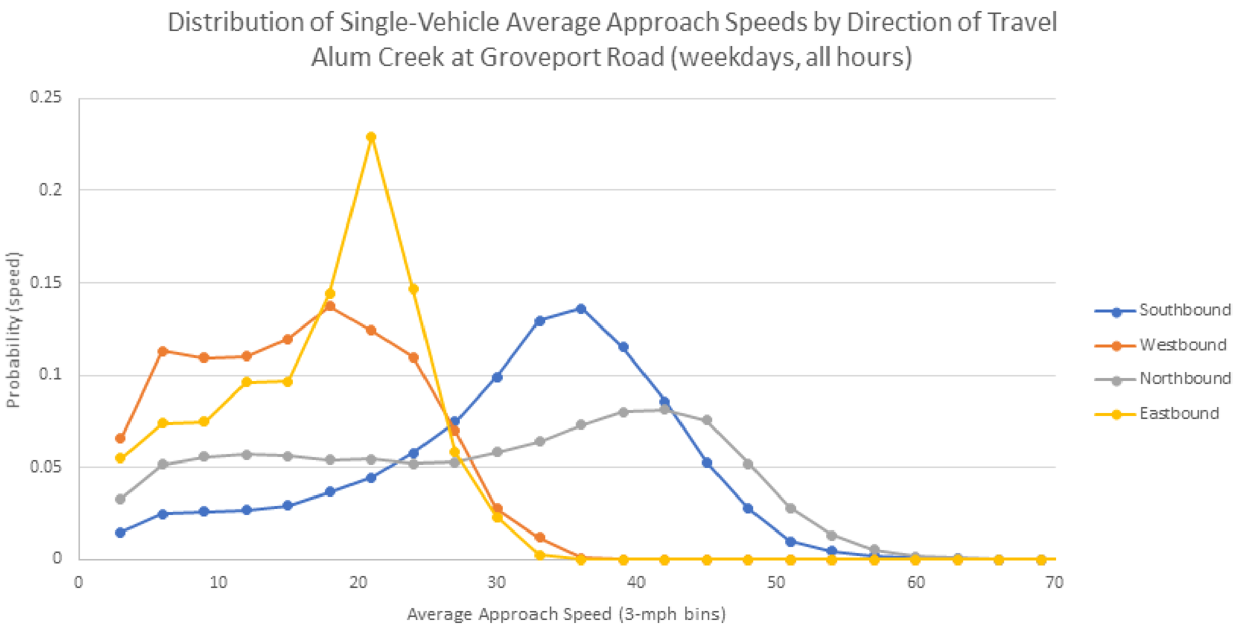


Figure 7-10: Approach Speeds

Source: City of Columbus

These analyses demonstrate the applicability of the CVE data to performing safety and other traffic-related studies and developing solutions tailored to specific problems at individual intersections. Using the CVE data in the OS, numerous other analyses are possible.

7.2.3.7. SUSTAINABILITY

Although the project demonstration, as funded by the USDOT Cooperative Agreement, ends May 31, 2021, the City intends to continue to maintain the CVE for the immediate future, so long as the radio spectrum currently licensed remains available for Dedicated Short Range Communications (DSRC) use. The data gathered in the OS, and from the Central Ohio Transit Authority (COTA) fleet continue to serve as a valuable measure of both the performance of the CVE, but also the traffic control systems in general. Fire and police will continue to be granted signal priority, and COTA is only just beginning to analyze the rich dataset available to it. To support these ongoing operations, the City of Columbus has negotiated separate contracts with both the roadside integrator and RSU vendor (Kapsch TrafficCom) and the OBU integrator (Siemens), both of which are expected to be available to the City for support through August of 2022.

7.2.4. Communications

The outreach and engagement goals for the CVE project were to:

- Recruit 200-300 private residents to install safety equipment in their personal vehicle
- Support the Institutional Review Board (IRB) exemption process
- Obtain informed consent from private drivers, as well as City of Columbus, Franklin County, COTA, and Dist-Trans (an ODW Logistics company) drivers to participate in the CVE study
- Solicit survey responses from private, City of Columbus, Franklin County, COTA, and Dist-Trans drivers

The communications team was responsible for recruitment of private resident drivers only. Coordination of vehicle commitments and installation for City of Columbus, Franklin County, COTA, and Dist-Trans drivers was managed by the technical team. The communications team also supported the IRB process for all driver types, including obtaining consent, training, and surveying.

7.2.4.1. STRATEGY

The communications team used a multichannel, staggered communications approach, largely relying on paid digital tactics. This created a more direct customer journey to joining the study and helped compensate for the COVID-19-related limitations on grassroots engagement.

STAGGERED INCENTIVE APPROACH

- **Helped the team capture contact information to use for follow-up to recruit participants**
- **Offering a $15 incentive also helped with word-of-mouth**
- **The team saw that once people had taken the prequalification and received the incentive, they told others they knew to sign up as well**

The customer journey mainly took place online until the participant showed up on-site for the installation appointment. The recruitment funnel started with the paid, earned, owned and shared tactics (described in **Chapter 3**) that directed people to take a prequalification questionnaire online. The questionnaire was built to automatically score the responses and send an email letting the prospective participants know whether they qualified. If they did qualify, they were directed to learn more about the study on the project website[71], schedule their installation appointment, and sent a $15 virtual reward card as incentive. An automated email campaign was set up to send reminders to qualified participants who had not yet booked their appointment, as well as to remind them of upcoming appointments. Upon completing installation of the safety equipment, private participants were given a $200 physical reward card. The team saw more success when people were guided directly to the prequalification questionnaire. Drop off was noted when people were directed first to the website with multiple call-to-action buttons to take the prequalification questionnaire.

Once installed, the private drivers were requested to take two surveys: one approximately 30 days after installation, and the second approximately 60 days after installation. Upon completion of the first survey, participants qualified for a $40 reward card. Upon completion of the second survey, participants qualified for a $60 reward card.

7.2.4.2. AUDIENCE

The priority audience for private participant recruiting were people who traveled (passed at least one intersection in) the CVE corridors at least three times a week. Initially, the team targeted this audience based on proximity to the corridor, but quickly learned that while home address was a good indicator that someone frequently travelled the corridor, it wasn't the only indicator. Broadening the audience allowed the team to reach people who drove within the corridor frequently for work, church, daycare, and retail.

The communications team used a combination of publicly available census data, demographic data, and psychographic research to develop messaging strategies. In order to influence people to make a decision on digital channels, it is important to understand individuals' situations and how the solution (a CVE unit) could make their lives better. Based on this research, potential participants were segmented into

[71] www.columbusconnectedcars.com

demographic and circumstantial groups. These groups have different concerns, and therefore are best reached by different messages.

The outcome of this research was messaging that related to potential users' current situations and explained why considering being a part of the CVE project engagement could benefit them. Based on their age and preferences, this gave the team a road map for what channel should be used to deliver the message (Facebook/Instagram/Google/Email) for the highest percentage chance of successful recruitment. This creates the most efficient environment to both manage and optimize digital campaigns while also building overall awareness of the program. The communications team encourages future projects to analyze their prospective participants and strive to deeply understand what motivates them to action and how best to reach them.

7.2.4.3. KEY MESSAGES

The key messages developed to reach potential participants included:

- *Smart Columbus is researching how to make the roads of [insert neighborhood] safer. Sign up to receive no-cost study-related safety equipment and earn up to $315!*
- *Smart Columbus is researching how CV technology can help Columbus drivers avoid crashes. Sign up today to see if you're eligible to participate!*
- *Want to help Smart Columbus learn how CV technology may help you avoid crashes? Sign up to receive study-related safety equipment and earn up to $315.*
- *[Insert neighborhood] residents, join the Smart Columbus Connected Cars program. You can receive no-cost safety equipment which may help you get around town. Sign up today and earn up to $315!*
- *Want to participate in transportation research through Smart Columbus? Sign up to learn more about the Connected Cars program and earn up to $315!*
- *Hey [insert neighborhood]! You can help Smart Columbus further transportation research. Sign up to participate and earn up to $315.*

7.2.4.4. SMALL-BUSINESS INSTALLER AND WORKFORCE DEVELOPMENT PROJECT

Workforce development was planned as part of the Smart Columbus Program from the beginning. The Program Management Office (PMO) saw an opportunity to work with local auto shops to perform the OBU installations, investing in small businesses and providing a workforce development opportunity to help individuals learn or expand a skillset in CV technology that could help them secure a future position in this area of work. Specific goals for the CVE project workforce development included:

- Identify 20 people willing to be paid $12 13 an hour for 200 hours of training, which included one week of formal training and three weeks of hands-on training assisting senior installers.
- Partner with one or more of the local colleges and universities to recruit technicians-in-training from their auto school, as well as provide a convenient installation location for faculty, staff and students.
- Identify at least two auto shops to provide convenient locations, show investment in the community and build trust in the program by having someone work on their vehicle that looks like them.

In May 2019, the project team (communications and installation staff) launched a short survey to gather information from local auto shops to identify good installation sites. Evaluation criteria included location, electronics expertise, number of technicians, customer amenities, number of bays that could be dedicated to the program, and location security. A team of five people worked to identify and contact auto shops within a few-mile radius of the corridor. It took a few months to contact all 120 shops and give them a reasonable chance to respond to this inquiry. From there, the installation team ranked the shops based on their answers.

In September 2019, the team conducted site visits at the top six shops. Based on the site visits, three auto shops and two higher education installation sites were selected to support installations. The installation team drafted compensation and terms agreements and worked with the sites to get them signed toward the end of 2019.

Unfortunately, COVID-19 impacted the team's ability to fully execute the vision. With fewer overall installations, it was not economically viable to engage more than one auto shop. Also, as a result of fewer overall installations, fewer technicians were needed; as such, the number was reduced but the wage was increased to $15 per hour. In addition, with higher education shifting to primarily remote classes, the higher education partner was also removed.

Figure 7-11: Site Visit at 2 Brothers Automotive

Source: City of Columbus

LOCAL INVOLVEMENT IMPACT

Based on our survey, **75%** of private drivers indicated working with a small-business installer **favorably impacted** their participation in the CVE project.

A meaningful success story for this project was partnering with the local shop 2 Brothers Automotive as the primary small-business installer. Based on the reduction in installations, new contract terms were negotiated to account for set costs related to each installation, hiring and training of the technicians, and other areas. The individuals who were hired into the ten training positions were diverse in age, gender, ethnicity, and work experience. Some of them had worked in an auto shop before, while others were interested in switching careers from their previous warehouse experience. At the end of the training, two of the trainees were hired full-time by 2 Brothers Automotive. The other individuals were provided a certificate of completion for the training program.

Figure 7-12: Connected Vehicle Technicians in Training

Source: City of Columbus

7.2.4.5. PROJECT LAUNCH

The launch of the CVE project involved two aspects: turning the system "on," including physical infrastructure, and also recruiting private participants willing to allow installation of in-vehicle equipment. On July 28, 2020, the City of Columbus hosted a virtual press conference to announce the launch of recruitment for the CVE, Smart Mobility Hubs and relaunch of the CEAV Linden Empowers All People (LEAP). Because all three projects had a large footprint in the Linden community, it made sense to launch them together. The announcement was covered by the Columbus Dispatch, Columbus Underground, and a local television station.

7.2.4.5.1 Prequalification

Prior to launch, the communications team worked with Community of Caring Development Foundation[72] to understand barriers to adoption, develop messaging, and inform strategy on how best to recruit within the community. The key barriers identified were:

- Privacy concerns:
  - Is the City tracking where I go?
  - Is that information being shared with police or other enforcement agencies?
- Installation concerns:
  - Will there be permanent damage to my vehicle?
  - Does my vehicle's age and condition allow installation of the equipment?

[72] *Community of Caring Foundation, described in **Chapter 3**, is the New Salem Baptist Church's nonprofit, community development corporation.*

- Participation concerns:
  - How long will the equipment be in my vehicle?
  - What do I have to do to earn the incentives?
  - How much is each incentive?
  - Where do I need to drive and how often?
  - What happens when the study is over?

Messaging was developed that addressed these concerns about participation and was used on the website and in follow-up emails. Building off lessons learned from the Tampa CV pilot, the communications team worked closely with the technical team to develop a prequalification questionnaire for prospective participants to determine if they met the criteria to join the study. Participation in the study required the following criteria:

- Must be over the age of 18
- Must have a valid driver's license
- Must have valid auto insurance
- Must have vehicle registered in their name
- Must have current vehicle registration
- Plans to keep vehicle through April 2021
- Plans to stay in the Central Ohio area through April 2021
- Does not have a convertible
- Does not have peeling paint or clear coat on their vehicle
- Must agree to the following
  - Placing a magnetic-mount antenna to the top of their vehicle
  - Having a 4-inch display which shows warning indicators mounted on their dashboard
  - Having wiring installed behind interior panels in their vehicle
  - Receiving visual and audio alerts about a dangerous situation while driving
- Must drive along the corridor at least three times a week.

The goals with the prequalification questionnaire were to obtain contact information so follow up could take place to ensure the prospective participants met basic criteria so they would not be turned away at the installation appointment. The questionnaire limited the number of on-site rejections to 13 participants, or 4% of total installations. Many of the on-site rejections were due to issues related to the condition of the vehicle. For example, a broken windshield would be difficult to determine without making the questionnaire too cumbersome. The team was successful in striking the right balance between obtaining the most pertinent information and making it easy to fill out.

Leading up to the launch, the primary communications goal was to drive awareness and build interest in participation. The communications team did this by sharing information at community meetings and using community partners' communication channels like email.

7.2.4.5.2 Recruiting

It was important for the communications team to be well connected to the technical team to determine when to launch recruitment. From both a technical and user experience perspective, it was crucial that system development was at a place where much of the technical risk had been mitigated, reducing the likelihood of performing any fixes or corrections post-installation. The communications team also sought to limit the number of participants that booked an installation appointment but did not complete an installation. It was therefore important to keep the window between the start of recruitment and first day of installation short.

Due to COVID-19, the CVE project recruitment was launched along with the Smart Mobility Hubs project and relaunch of the Linden LEAP via virtual press conference and press release on July 28, 2020. Installations began September 8, 2020 and ended December 18, 2020. This lead time – approximately four weeks – met the communications team's goal of reduced lead time between recruiting and installations. Multiple tactics were used during the time period between the launch in July and the completion of installations in December, with the goal of meeting the target number of private participants (between 200-400) and increasing awareness in the community. These tactics included a mix of paid, earned, owned and shared. **Figure 7-13** provides the specific tools used within each of these tactics.

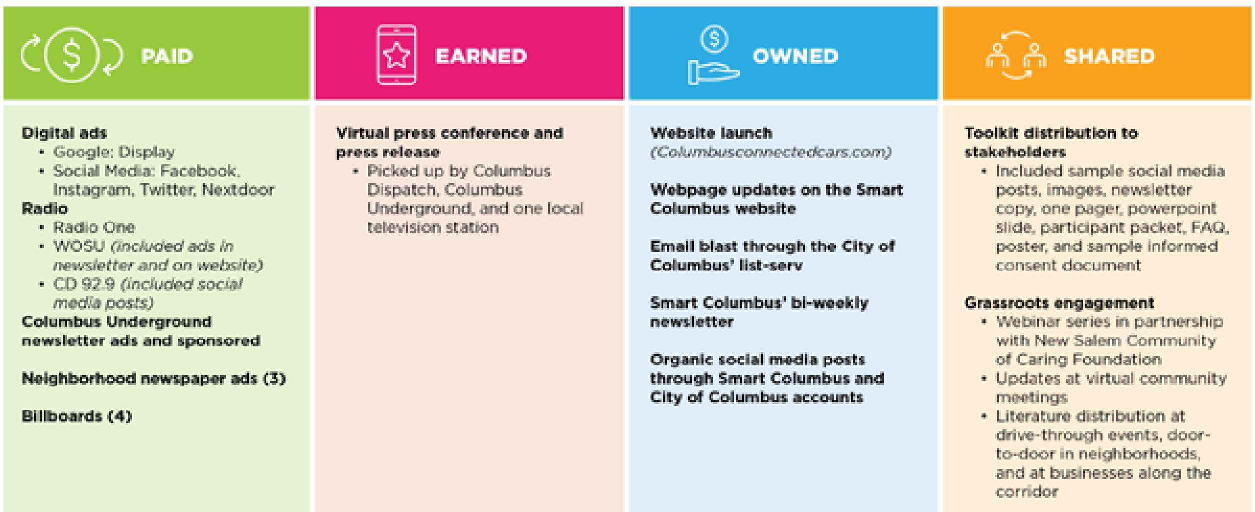


Figure 7-13: Digital Recruiting Strategy

Source: City of Columbus

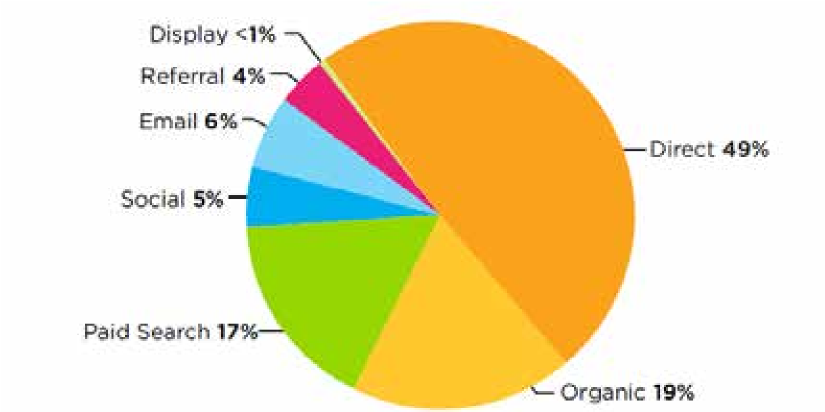
Overall, the communications team was successful in reaching all the outreach and engagement goals for this project.

Table 22: Connected Vehicle Environment Outreach and Engagement Statistics

Website Users	Completed Prequalification Questionnaire	Booked Installation Appointment	Completed Installation
5,019	Ÿ 1,190 total Ÿ 702 qualified Ÿ 488 disqualified	403	311

Source: City of Columbus

Overall, a 26% conversion rate was achieved from prequalification (1,190) to installation (311).



Source / Medium	Sessions	%
Direct	1,740	49%
Organic	657	19%
Paid Search	594	17%
Social	177	5%
Email	217	6%
Referral	148	4%
Display	17	0%
Total	**3,550**	**100%**

Figure 7-14: Connected Vehicle Environment Traffic Channel Groupings

Source: City of Columbus

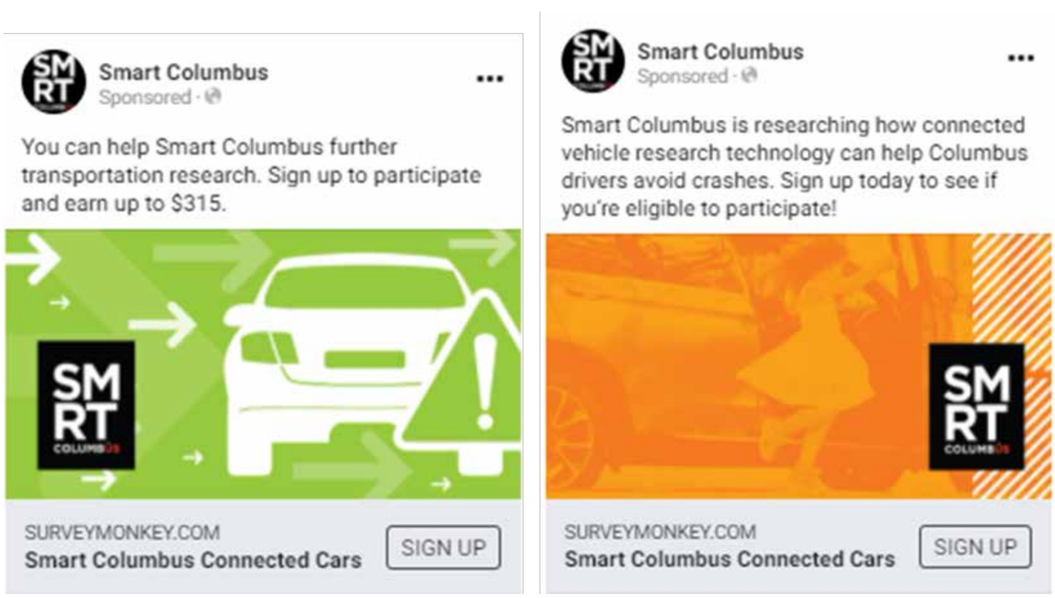


Figure 7-15: Connected Vehicle Environment Facebook Ads

Source: City of Columbus

Other findings from the recruitment efforts include:

- The largest number of participants came from the Linden area (43211 and 43224 zip codes), accounting for 21% of all participants, which demonstrated that the goal of reaching this community was achieved with the tactics employed.
- The second largest number of participants (18%) came from the nearby neighborhoods of Olde North, Beechwold, Clintonville, and Worthington.

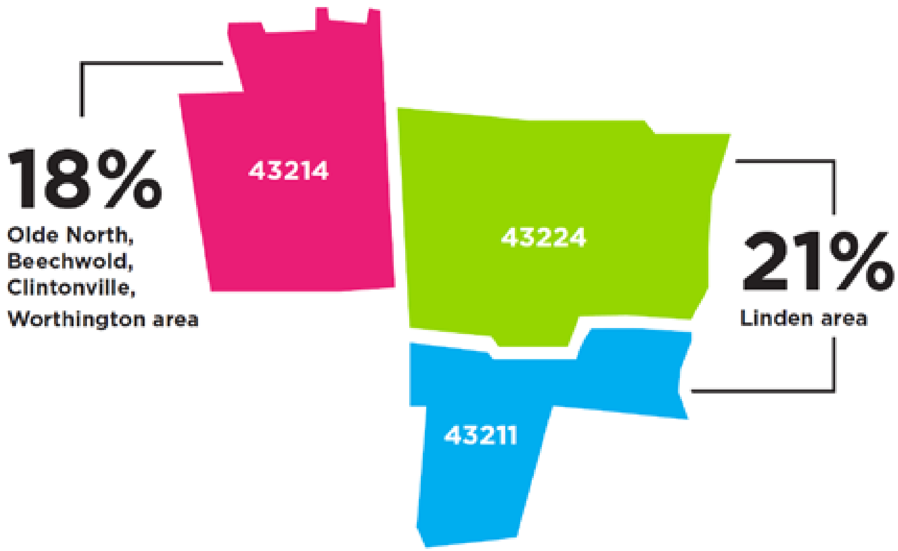


Figure 7-16: Connected Vehicle Environment Participant Distribution

Source: City of Columbus

7.2.4.5.3 Training and Institutional Review Board

All recruitment and participant-facing communications were submitted for approval by the IRB prior to distribution. This process was a crucial element of recruiting and training, and one that was ongoing from the initial development of materials through to the distribution of the performance measurement surveys. The IRB process began with the drafting of the research protocol, which documented the purpose of the project and the risks to and protections of the human participants. The first submission, in November 2019, also included the recruitment plan.

A key element of the IRB submittal was the informed consent document (ICD), which explains the purpose of the study, potential benefits/risks to participant, and outline what is expected of the participant as part of the study. The IRB would not review the submission until these forms were included. Because the Smart Columbus CVE project included both public and private participants, multiple versions had to be submitted. The versions varied because of the amount of personally identifiable information (PII) collected, how drivers were receiving their training, how surveys were disseminated, and whether drivers were getting an incentive:

- The private driver ICD required the most information. These drivers have a HUD, which made the training a little more robust and required reference materials to take home. The communications team also had to collect minimal PII to facilitate individual survey responses to facilitate the incentives.

- For City of Columbus, Franklin County, COTA, and Dist-Trans fleet drivers, no incentive was provided to complete the surveys. Therefore, the communications team did not need to collect any PII, which downgraded the consent level to verbal consent only. The trainings and surveys were facilitated through Columbus' virtual training portal (City employees) or through the drivers' supervisors.

Before installation took place, the prospective participant needed to review and sign (or verbally consent to) an ICD. The communications team developed a video to describe the purpose and key information shared in the informed consent to ensure each participant received the same information about the study. The communications team also developed a driver training video that was shown to the participants to share information about the alerts they may receive and the surveys. Similar videos were also developed for City of Columbus, Franklin County, COTA, and Dist-Trans drivers. These training videos provided an overview of the device, familiarization to the alerts and warnings they would provide, and contact information and resources for follow up questions.

Another aspect of IRB was the certification of all staff who had to engage and interact with participants. Staff who worked at the installation sites went through a human-research subject training to be able to facilitate the signing of the ICD documents on-site.

Lastly, the IRB also had to review and approve the performance measurement surveys that were collected post-launch. As with the ICDs, multiple surveys were developed to capture feedback from the different vehicle classes that were equipped with OBUs and HUDs. There were surveys prepared for private drivers (two surveys to capture whether sustained use yielded different feedback), City of Columbus, Franklin County and COTA fleet drivers and heavy-duty vehicle drivers from Dist-Trans (to evaluate the freight signal priority application). While the ICD and protocol should be submitted together, other items such as the recruitment plan and surveys can be submitted individually. A full list of the submissions is contained in the Human Use Approval Summary[73].

[73] https://d2rfd3nxvhnf29.cloudfront.net/2021-03/SCC-F-Human%20Use%20Approval%20Summary-Update-v3%20with%20attachments%203.25.21.pdf

7.2.5. Project Costs

The following charts and **Table 7-6** show the actual project costs broken out by deployment, operations, and specific vendors. Deployment covers the time from project beginning until the launch on October 16, 2020. Operations is launch until the end of the demonstration period.

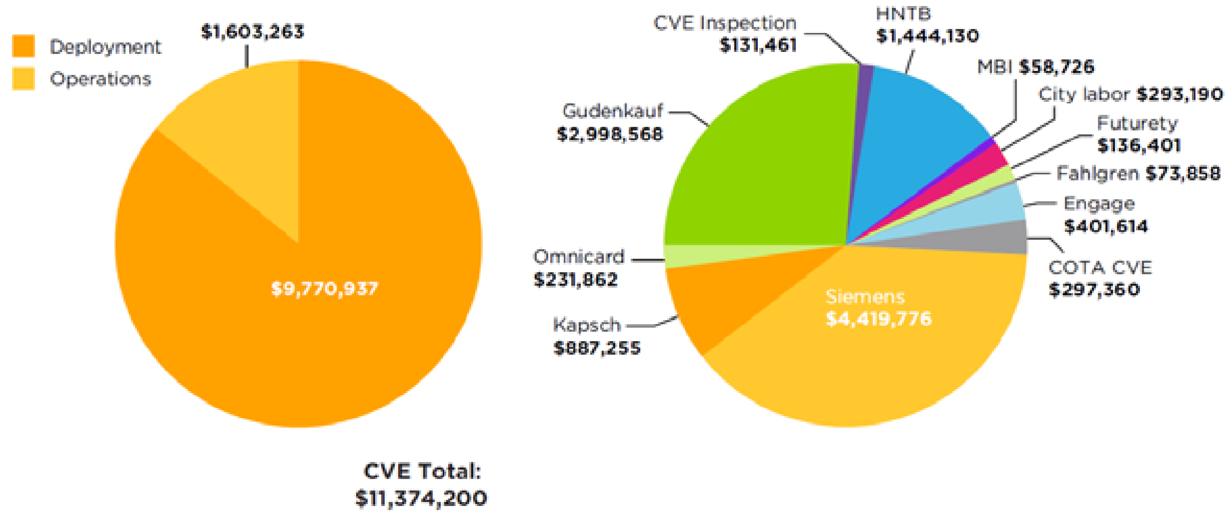


Table 23: Deployment and Operations Costs for the Connected Vehicle Environment Project

Vendor Actuals	Deployment	Operations	Total
COTA CVE	$297,360	-	$297,360
Siemens (Brandmotion)	$4,200,408	$219,369	$4,419,776
Kapsch (Danlaw, Econolite, PathMaster)	$850,354	$36,901	$887,255
Omnicard	$120,368	$111,494	$231,862
Gudenkauf	$2,054,917	$943,651	$2,998,568
CVE Inspection	$112,204	$19,257	$131,461
HNTB (WSP, CCI, SSI, AEC, Advarra)	$1,345,516	$98,613	$1,444,130
MBI	$52,115	$6,611	$58,726
City Labor	$250,757	$42,433	$293,190
Futurety	$101,486	$34,915	$136,401
Fahlgren	$63,996	$9,862	$73,858
Engage (Murphy Epson)	$321,455	$80,158	$401,614
Total	**$9,770,937**	**$1,603,263**	**$11,374,200**

Source: City of Columbus

Table 7-7 and **Table 7-8** provide recurring costs and the party responsible for each cost related to the project's operation and maintenance during and after the demonstration.

Table 24: Recurring and Support Costs During Demonstration

Description	Cost	Responsible Party	Comments
AT&T IPv6 Internet Service	$150/month	City of Columbus	Required to access external resources, such as the SCMS
SCMSX.509 SCMS Certificates (IEEE 1609.2)	$10/OBU annually $60/RSU annually	DriveOhio	Annual fee covered by DriveOhio for first 2 years
Integrator Support	Part of integrator contract	Kapsch, Siemens	

Source: City of Columbus

Table 25: Recurring and Support Costs After Demonstration

Description	Cost	Responsible Party	Comments
AT&T IPv6 Internet Service	$150/month	City of Columbus	Required to access external resources, such as the SCMS
SCMSX.509SCMS Certificates (IEEE 1609.2)	$10/OBU annually $60/RSU annually	City of Columbus	City to assume cost beginning in 2022
RSU Support	$150,000	Kapsch	15-month period from May 2021 thru July 31, 2022
OBU Support	$160,000/year (est.)	Siemens	Starting June 2021 thru August 30, 2022

Source: City of Columbus

7.2.5.1. KEY LEVERAGED PARTNER CONTRIBUTIONS

Table 7-9 provides the contributions of key leveraged partners that are not included in the project costs.

Table 26: Summary of Contributions by Key Leveraged Partner

Partner	Estimated Amount	Description/Item
COTA	Specific amount for CVE not disclosed	Ÿ In-kind staff to support CVE Ÿ Participated in systems engineering process (user needs, concept definition and requirements development) Ÿ Attended regular project status meetings Ÿ Coordinated COTA vehicle installations Ÿ Assisted development of Transit Vehicle Interaction Event Recording (TVIER) application

Partner	Estimated Amount	Description/Item
Siemens	$61,300	Ÿ Supplied 10 RSUs Ÿ Supplied 2 licenses for CV-enabled traffic signal controller
Franklin County	$2,000,000	Ÿ Design and construction for CVE Alum Creek corridor Ÿ Intersection geometry and mapping Ÿ Participated in status and design project meetings
ODOT	Specific amount for CVE not disclosed	Data services including SCMS and position correction

Source: City of Columbus

7.2.6. Project Stakeholders

Each project was led by the PMO, with vendor support playing a critical role in implementation. Vendors were primarily responsible for planning, documentation, testing and integration, and delivery of system functionality. For CVE, these vendors and their roles are summarized in **Table 7-10.**

Table 27: Connected Vehicle Environment Project Vendor Responsibilities

Vendor	Role/Responsibility
Kapsch (DanLaw, Econolite, Path Master)	RSU System Integrator, RSU Supplier, Controller Equipment Supplier, System Implementation
Siemens (Brandmotion)	OBU System Integrator, OBU Installation, Installer Training, Informed Consent
Gudenkauf	RSU and network equipment installer
HNTB (WSP, CCI, SSI, AEC, Advarra)	Technical lead for systems engineering, testing, integration; responsible for all Cooperative Agreement deliverables, installation plan development, IRB
OmniCard	Incentives
Michael Baker International	HMI Design Review
Engage	Outreach and engagement
Futurety	Recruitment and adoption
Fahlgren	Recruitment and adoption
City of Columbus	Inspection of CVE Installations (note: this was a separate City expense from project coordination by the PMO and network configuration by the City's Department of Technology, as it was invoiced as part of the Gudenkauf construction contract).
Franklin County	Intersection mapping and equipment installation

Source: City of Columbus

THE CITY OF COLUMBUS ANDREW J. GINTHER, MAYOR

While the project team worked throughout the Cooperative Agreement to develop, deliver, operate and maintain the CVE project, many diverse groups came together to make the project successful. **Table 7-11** summarizes the specific stakeholders that were engaged, and categorizes their contributions into three areas to indicate when their participation was used:

- **Systems Engineering –** These organizations/groups contributed to defining end-user needs, ConOps or system requirements documentation
- **Development –** These organizations/groups contributed to the build out of the project. This includes installation, integration, testing, and recruitment/outreach planning
- **Demonstration –** These organizations/groups contributed to the operations and maintenance of the project from go-live to end of the demonstration

Table 28: Connected Vehicle Environment Project Stakeholders

Stakeholders	Systems Engineering	Development	Demonstration
Government			
USDOT	X	X	X
City of Columbus Department of Public Service	X	X	X
ODOT/DriveOhio	X	X	X
Franklin County Engineer's Office	X	X	X
City of Columbus Department of Technology	X	X	X
City of Columbus Department of Public Safety – Division of Fire	X	X	X
City of Columbus Department of Public Safety – Division of Police	X	X	X
City of Columbus Department of Development		X	X
City of Columbus Department of Finance and Management – Fleet Management	X	X	X
City of Columbus Department of Neighborhoods			X
Village of Obetz	X	X	X
Mifflin Township	X		
Clinton Township	X		
Private Entities			
COTA	X	X	X
Dist-Trans (an ODW Logistics company)		X	X
American Federation of State, County and Municipal Employees Local 1632 and 2191		X	X
Communication Workers of America Local 4502		X	X

Stakeholders	Systems Engineering	Development	Demonstration
Fraternal Order of Police, Lodge 9		X	X
International Association of Fire Fighters Local 67		X	X
2 Brothers Automotive		X	X
Siemens (Smart Columbus Partner)		X	
Collision Avoidance Metrics Partnership	X		
Advocates/Grassroots			
City of Columbus Area Commissions		X	X
Residents who live or work along CVE corridor		X	X
Educational			
OSU	X		
Columbus State Community College (CSCC)		X	

Source: City of Columbus

7.3. PROJECT EVOLUTION

The CVE project was one of the 15 original projects outlined in the City's proposal to the USDOT SCC in 2016. Although deployed with a smaller number of participants and a few less CV applications than originally intended, the CVE project remained consistent with the original goals and support of the USDOT Vision Elements.

7.3.1. Changes

Changes to the CVE project are organized into three separate but interrelated categories: scope, cost and schedule, and stakeholders and partners.

7.3.1.1. SCOPE

Three major changes to the scope of the CVE project relate to changes in the specific applications deployed, the size of the deployment, and the radio frequency spectrum on which the CVE was deployed. The first two, the CV applications and the size of deployment are related. Changes in the radio frequency spectrum available for the V2X communications was an unanticipated change levied from the Federal Communications Commission (FCC). The CVE project was also affected by changes in scope to the Connected Electric Automated Vehicles (CEAV) project, and the elimination of Smart Streetlighting and Truck Platooning projects from the Smart Columbus Program.

7.3.1.1.1 Connected Vehicle Application Simplification

The CVE project portion of the Smart Columbus proposal originally included a total of 19 CV applications, including pedestrian and bicycle focused applications among multiple vehicle safety and mobility applications. However, in early 2018, the CVE project team performed a technology readiness level (TRL) assessment of the 19 proposed CV applications. The technology readiness of each application was assessed by a rubric that generates “grades” ranging from a simple concept having little-to-no documented needs or requirements (1-3); to early through advanced prototypes (4-6); to full commercial availability (7-9).

Of the 19 applications, two applications were graded as a 1; six were graded as 7; and the remainder fell in the 3-6 range; therefore, many of the proposed CV applications were not technically mature enough to be deployed without substantial development and testing, introducing uncertainty and risk into the scope and schedule.

Further, by participating in the USDOT Pilots’ biweekly technical roundtable calls, and learning from the shared deployment experiences, the priority was placed on applications with a high technical readiness level as defined in the CVE ConOps, and the following applications were removed from the project:

- Bicycle Approaching Indication/Bicycle Passing Distance Warning
- Emergency Vehicle Alert
- Transit Vehicle at Station/Stop Warning
- Vehicle Turning Right in Front of a Transit Vehicle
- Active Response Collision Warning
- Pedestrian in Signalized Crosswalk Warning
- Transit Pedestrian Indication
- Warnings about Upcoming Work Zone

In addition, Intent-to-Platoon was eliminated in May 2019 when the Truck Platooning project was removed from the Smart Columbus Program.

TVIER was later added in response to interest by COTA to capture application event data that would normally be displayed on the HUD. These changes brought the final total to 11 CV applications.

7.3.1.1.2 Size of the Deployment

Concurrent with the reduction in the number of CV applications agreed to in April 2018, the proposed quantity of roadside and in-vehicle installations was re-evaluated. As with the number and type of applications, lessons learned from the CV Pilots were instrumental in revising the number of vehicles, in particular the private participants, to a number that was achievable within the proposed schedule and budget. This reduction was from an initial target of 3,000 vehicles to a range of 1,500-1,800 (depending on the number of private participants). Subsequent events after this initial project-wide response further revised target numbers to the final target of 1,000-1,200. The initial reduction in the number of vehicles included the following:

- The original target for onboard units had been 3,000 vehicles, but in eliminating the bicycle application, 100 CoGo bicycles were removed from consideration.
- Columbus City Schools buses, originally 50 of the planned vehicles, were also removed from the deployment list due to limited resources, changes in personnel and the reduction of deployment locations for the Reduced Speed School Zone Warning application.
- City of Columbus fleets within the Department of Public Service and the Division of Fire were also reduced by 170 vehicles, mostly to reduce the infrastructure footprint.
- After conversations with the CV Pilots and as a result of local community outreach, the target number of private vehicles was reduced to slightly under 1,000.
- During this same period, COTA offered 150 additional vehicles to be equipped.

- In April 2018, the revised target installation was 1,500-1,800 vehicles. Subsequent reductions were due to the impacts of the COVID-19 pandemic on public outreach and recruiting, and the delays it caused in rolling out the CVE. This resulted in a revised goal for private installs to 300, bringing the overall project vehicle installation goal to slightly under 1,000 vehicles.

With an added push within City of Columbus operations, the CVE project exceeded the revised private installation goal by nearly 4%, with 311 private installations being completed. Ultimately, the final count of equipped vehicles was 1,037.

The reduction in the number of RSUs to be deployed occurred over three phases, initially reducing the original RSU count from 194 to 156, then to 113 and ultimately down to 85, which is the quantity currently in operation. The rationale for these reductions occurred over time, and are summarized next in chronological order:

- With the decision to remove the Smart Streetlighting project from the USDOT portfolio in mid-2017, the CVE project budget alone was not adequate to deploy the necessary communications (i.e., fiber) for 38 locations, primarily on low-volume, low-speed, non-signalized 'neighborhood' streets that had originally been selected in conjunction with school zones. Generally, these locations lacked the necessary communications backbone to support their deployment, but when originally selected, had intended to piggyback on the Smart Streetlighting (with Wi-Fi) project.
- In April of 2018, concurrent with the simplification of the project scope, 43 additional RSU sites were eliminated in the following locations:
  - Road construction along High Street south of 5th Avenue eliminated 22 locations.
  - Nine locations along Cleveland Avenue south of 2nd Avenue were also eliminated as these were outside of the region in which COTA operated transit-signal priority.
  - Seven locations along Stelzer Road, in the Easton area, were eliminated as part of the separate program-level decision to relocate the CEAV deployment away from the Easton region.
  - Five locations along Alum Creek Drive north of I-270 were also removed, as these were related to the operational routes originally planned for freight signal priority that did not prove necessary upon finalizing the route with partner Dist-Trans.
- The final reduction in RSU locations concurred with the elimination of the Truck Platooning project from the Smart Columbus project portfolio in May 2019. At this same time, a final evaluation of the remaining sites, and their expected volumes/value was made, eliminating a total of 28 more, and settling on a final number of 85 RSUs, which is the current number. These reductions included:
  - The remaining 13 locations in the Easton area, all south of the Morse Road corridor. These locations were intended to support enhanced COTA traffic signal priority operations (in conjunction with CEAV), but with the change of location for CEAV (discussed earlier), and the route redesign COTA introduced in 2018, these no longer served the same role as originally planned.
  - Five locations along Wilson Road at Trabue Avenue on Columbus' west side, six in Byesville, OH, and one in the Alum Creek corridor. These were all in support of the Intent-to-Platoon application for the eliminated Truck Platooning project.

- Three additional locations along High Street were eliminated as the current traffic signal warrants[74] at those locations were not met and called for the removal of the signals.

7.3.1.1.3 Spectrum Change

In November of 2019, the FCC announced that it was intending to issue a Notice of Proposed Rulemaking (NPRM) that would repurpose the lower 45 MHz of the 75 MHz band that was currently allocated for use by DSRC and make it available for unlicensed Wi-Fi, referred to as UNII-3. At the time of this announcement, the CVE project was occupying two-thirds of this spectrum, deploying crash-imminent safety messages on what is known as the safety channel – Channel 172 – a 10-MHz slot in the low end of the spectrum. Additionally, the CVE design called for the use of Channel 178 as the primary control channel for all other messages, and three 10-MHz service channels at 174, 176 and 180. This original channel alignment was consistent with other CV deployments nationwide, and compliant with statewide guidance developed by DriveOhio[75].

After a tradeoff analysis was performed in January 2020, and in consultation with USDOT, the PMO revised the system requirement to deploy all V2I communications (those between RSU and OBU) on Channel 180 exclusively. As OBUs do not require licensing, a decision was made to retain the V2V communications on Channel 172. This required changes to device configuration, and additional testing, both of which had schedule and cost impact. The decision by the PMO has proven to be the correct one in the near term as coincident with the NPRM, the FCC ceased issuing any licenses for DSRC deployments other than on Channel 180. Columbus had not yet initiated RSU licensing at the time of the FCC announcement, but subsequent licenses on Channel 180 were all approved in due time.

Siemens Overcomes FCC Challenges to Launch CVE Demonstration

Siemens has been following the FCC changes closely knowing that it would have a big impact on the CVE project. In November of 2019, FCC issued the use of the 5.850-5.925 GHz Band Notice of Proposed Rulemaking that sought comments on a proposal to repurpose ITS spectrum. As a result, in December of 2019 FCC issued a Public Notice limiting the registration of the new DSRC RSUs to Channel 180 only. This change came in the middle of the Columbus CVE project. "As an active member of multiple ITS organizations, such as ITS America, NTCIP, OmniAir, and others, we actively helped to develop standards and procedures to comply with the new FCC regulations." Implementation and testing of these steps in Columbus made it possible for the CVE project to overcome the challenges and stay on track. **"We developed and implemented procedures to reconfigure deployed OBUs and RSU to meet Channel 180 requirements. The changes were tested and deployed with a minimal effect on the project's progress."**

Venkatesh Jadhav, Manager, Project Management, Siemens

[74] *Studies of traffic signals on major thoroughfares such as High Street must meet certain criteria before traffic signals can be installed or replaced. These studies determine if signals are "warranted" by the cross-traffic or pedestrian volumes.*

[75] *https://www.ghsiss.com/v2x/driveohio/*

7.3.1.2. COST AND SCHEDULE

Despite changes to the original scope and unexpected external challenges (FCC ruling and COVID-19), the PMO delivered a fully functioning CVE project with 11 applications, over 1,000 participants, 85 RSU intersections, and terabytes of rich CV data. All the deliverable requirements were met in terms of system engineering documentation, test results and performance measures. In addition, the value of the lessons learned cannot be underestimated, particularly in terms of advancing interoperability – the Smart Columbus CV environment comprises RSUs from three different vendors, all managed under a single system, and this was the first large-scale deployment of a single channel V2I environment. That said, what the original scope would have required in terms of overall budget or schedule was not determined, but it is likely that the project as originally conceived would have taken longer and been more costly.

As the project evolved, the reduction in the quantities of both RSUs and OBUs reduced the equipment and installation costs. The following schedule-related activities discuss impacts resulting from project changes:

- **Systems Engineering Process (nine months' delay) –** Systems engineering took longer than anticipated to engage stakeholders, develop the ConOps, revisit the systems engineering approach with design changes due to the FCC channel allocation, and revisit this documentation once RSU and OBU integrators were brought on board in mid-2019.
- **Scope Simplification (new: three months' delay) –** Evaluation, justification and adjustment of scope.
- **Procurement Process (three to five months' delay) –** the City of Columbus procurement timeline was not sufficiently accounted for during project development stages in 2016.
- **FCC NPRM (new: four months' delay) –** Shift to use of single channel for V2I application. Impacts to systems engineering and regression testing due to additional tests.
- **Integration Testing (four months' delay) –** COVID-19 restrictions effectively shut down full on-site lab and test events just as they were ramping up. These events did proceed using a combination of local and remote staff throughout the spring and summer of 2020, but this approach was not as effective as the original plan and delayed final launch from July 2020 to October 2020.
- **Installation Start (two months' delay) –** Delivery delays, attributable to COVID-19 restrictions, both foreign and domestic, and the resulting disruption of the supply chain affected delivery of new fleet vehicles targeted for CV installation and in-vehicle hardware sourcing, delaying the start of device installation from July 2020 to September 2020.
- **Installation Period (six months' delay) –** Longer per-vehicle estimates than originally planned; although private installations proceeded on track, fleet vehicles required additional time. The CVE project team seized the opportunity to begin installations on fleet vehicles when they were largely sidelined in spring 2020 due to COVID-19, but then had to schedule additional time to activate OBUs after launch in October 2020 due to COVID-19 travel restrictions.

The FCC's reallocation of the 5.9 GHz safety spectrum, and the travel restrictions and material delivery delays that occurred due to COVID-19 caused the most significant project delays. In addition to these delays and added scope, the time frame for data collection was decreased: Data were collected for five months – from November 2020 to March 31, 2021 – instead of the 12 months as was originally planned.

7.3.1.3. STAKEHOLDERS AND PARTNERS

Stakeholders and partners of the CVE project span both the private and public sector. Many of these joined the City of Columbus during the development of the SCC application, while others were added post-award. These groups played a key role in defining the CVE project concept and bringing the project from design to demonstration. Most were consulted throughout the life of the project, with recurring weekly or monthly meetings depending on the technical and collaborative needs of the project at the time. Further, stakeholders had access to all project documentation via the project SharePoint file-sharing site.

Upon award of the RSU integrator, OBU integrator, and construction contracts, the bi-weekly meetings expanded to include members of the vendor teams (Kapsch, Siemens, Gudenkauf, and subcontractors), which continued throughout the life of each contract. Finally, for the duration of the construction and integration activities, a bi-weekly, high-level, high-priority status meeting was held to include USDOT, the integrators, the PMO, and the City of Columbus Department of Technology, Division of Traffic Management, and Division of Design & Construction.

Local CVE project partners that did not ultimately remain part of the project include the fire departments for Mifflin and Clinton Townships. Both were originally intended to have CV equipment installed to support EVP, but the combination of delays and uncertainty in the future of the technology given the FCC NPRM resulted in a decision to forego their inclusion. Additionally, the PMO initially pursued several relationships to explore options for completing vehicle installations around the City. One option was the use of CSCC and its staff/students to assist in completing private installs. Although the two parties engaged throughout the course of the systems engineering phase, ultimately changes in leadership at CSCC and reduced resources due to COVID-19 impacted CSCC's ability to serve as an installation site.

A partner whose role evolved over the course of the Smart Columbus Program was Dist-Trans Co., LLC (a subsidiary of ODW Logistics). Originally, this freight company was a partner on the Truck Platooning project. Dist-Trans wished to remain involved when that project was removed from the Smart Columbus Program, and offered its fleet vehicles for the CVE project to help analyze the freight signal priority application.

7.3.2. Challenges

The previous section identified and discussed the changes to scope, schedule, budget and partners that occurred over the life of the CVE project. In most cases, a high-level root cause is identified in conjunction with the change, such as the lessons learned from the USDOT CV Pilots, the impact of the FCC NPRM and the changes of partners. These specific challenges tie back to the overall maturation of the CVE project and the expectation for change over the course of the demonstration period. This section is therefore intended to provide an understanding of how the activities within the CV industry as a whole impacted the CVE project from planning to execution.

The readiness and availability of this technology was overestimated at the time of application and in the early phases of the SCC, and decisions by both NHTSA and the FCC further contributed to limited advancement of the technologies. As an example, Columbus envisioned advancing to demonstration just as the CV Pilots had advanced on the heels of the Safety Pilot Model Deployment. The success of the Safety Pilot provided the impetus for the proposed 2016 NHTSA rulemaking to require DSRC as standard equipment on light-duty vehicles in the future. Simultaneously, the original equipment manufacturers (OEMs) such as GM and Toyota, were making great advances and trade events such as ITS World Congress were full of CV-related demonstrations. The Smart Columbus CVE project was founded on a belief that the multiple, ongoing activities were an indicator that DSRC would continue to mature, and the applications would continue to emerge and be "production-ready," as would the hardware, in time for the Smart Columbus CVE project demonstration schedule. The project team anticipated that lessons learned from other large-scale V2I deployments would be an invaluable resource in development, and the outcomes of the Smart Columbus CVE project would be, in turn, an example for how other midsized cities could deploy and sustain their own CV infrastructure.

However, instead of research and products advancing at the same or higher pace as they were at the time of the SCC application, the CV industry instead came to a standstill, first with NHTSA pausing its proposed DSRC mandate, followed by the disruption when the FCC NPRM was issued. With each of these events, CV research and development slowed and pivoted to realigning operations with the available spectrum and maturation regressed. The CV Pilots continued, but not at the original planned pace, and rather than continued advancement and development of standards, efforts moved towards defending the technology and the spectrum. Paramount to these events was what was happening in the industry and its regulatory environment. Although the CVE project proceeded, it was with the uncertainty of this environment constantly presenting new and evolving risks.

- In the fall of 2017, the NHTSA NPRM[76] mandating DSRC for light-duty vehicles, which had been pending, was put on an indefinite hold by the new administration.
- Cellular V2X (C-V2X), an emerging technology based on 4G Long-Term Evolution (LTE), was also starting to pressure the industry and decision makers to consider this alternative technology instead of DSRC.
- The push for not just CVs, but connected autonomous vehicles (CAVs), redirected much of the focus of the automotive industry to the benefits of advanced driver assist systems (ADAS) and automated driving systems (ADS). Many of the same technology providers supporting CV were now shifting to support these emerging markets, further diminishing the perceived value of research and development of CV-enabled technologies.

The effects of these issues on the CVE project were largely captured in the previous section, but further insights into these impacts are outlined below:

- The results of the technology readiness review performed by the CVE project team in early 2018 revealed no real advancement of the applications during the two-years since the original plan developed in 2016. This was not what Columbus had expected and was part of the impetus for eliminating several of the lower scoring applications. Without the hold on the NHTSA rulemaking, more of the proposed applications would likely have met the minimal criteria.
- CV equipment procurement was also impacted. During the application process, nearly every single equipment vendor (almost ten at the time in 2015-2016) reached out to Smart Columbus. However, by the time the PMO proceeded with procurement of integrators (and equipment) in mid-2019, only three bids each for the infrastructure and the in-vehicle units were received. While the City is confident with the integrators it chose, the state of the CV industry, instead of being three years further advanced, was essentially in the same place as 2016.
- The project's integration activities and testing, which were planning to leverage the CV Pilot lessons learned, were instead nearly on par with their efforts. While additional time was built into the schedule from the start, this time was used not only to test and integrate applications, but also to respond and adjust to the FCC NPRM's spectrum reallocation proposal.

The final FCC ruling upended the intended deployment model that more than a decade of research and testing with DSRC on multiple channels had established. Suddenly, in a period of only a few months, testing now had to be redirected to explore how effective and scalable a single channel deployment could be. The CVE project pushed ahead and found that a single channel could support the defined applications with a load of five vehicles. No attempts were made to scale beyond that size, as this was deemed sufficient to support the demonstration period and data gathering to support the performance measures.

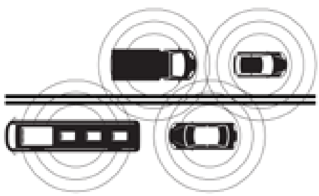
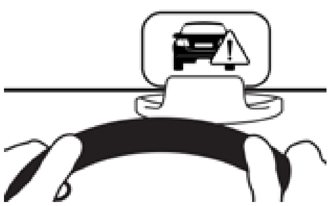
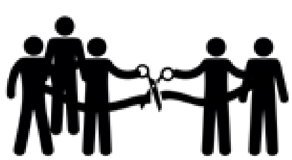
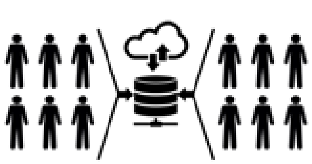
In the end, every challenge was overcome, but not without some degree of redirection, compromise in how requirements where implemented, and simply additional effort. These changes are reflected in the final as-built set of systems engineering documentation related to the CVE project.

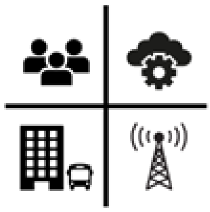
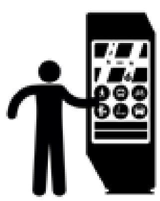
[76] https://www.federalregister.gov/documents/2017/01/12/2016-31059/federal-motor-vehicle-safety-standards-v2v-communications

7.4. CONCLUSIONS, LESSONS LEARNED AND RECOMMENDATIONS

In evaluating the qualitative and quantitative results, the CVE project addressed Columbus challenges and met several of the original expectations defined in the Columbus Smart City vision. The project addressed transportation challenges by deploying infrastructure applications and strategies in the following USDOT Vision Elements in **Table 7-12**.

Table 29: Connected Vehicle Environment Project Relationship to USDOT Vision Elements

VISION ELEMENT #2 Connected Vehicle 	The three key elements of this vision are the use of V2V and V2I communications to enable safety, mobility, and environmental applications, the use of the data from equipped vehicles to provide insights to transportation operators, and the use of DSRC as the platform to deliver the solution. Although the final aspect of this vision is currently in question at the Federal level, the CVE project not only delivered on this functionality but also demonstrated a revised approach of using only two channels to deliver the applications. The suite of applications that were selected and successfully implemented directly tie to the other two aspects of this vision. Of the 11 applications deployed, nine of them had a focus on safety and mobility while the remaining two provided both City and transit operational staff with additional data generated by the vehicles and infrastructure.
VISION ELEMENT #3 Intelligent, Sensor-based Infrastructure 	The deployment of RSUs and applications geared toward transportation operators at the City of Columbus and COTA have expanded the intelligent infrastructure in the City. This infrastructure expands the traffic related data collected by the City of Columbus, and the applications (especially the traffic-focused VDTO and the transit-focused TVIER) demonstrate how stakeholders can integrate this data into their existing operations, creating a more robust data source and identifying potential gaps and areas for improvement. Examples of this were shown in **Section 7.2.3.4**.
VISION ELEMENT #7 Strategic Business Models and Partnering 	This Vision Element focuses on leveraging public-private partnerships, especially noting the contribution of universities; however, the CVE project demonstrated another key aspect of this vision: workforce development. While private companies, nonprofits and academic institutions are key to advancing smart city solutions, the community must be involved and engaged to ensure sustainability. Working with local auto repair shops, training them on emerging technology, and educating them on the capabilities and benefits contributed to the overall advancement and acceptance of the technology. CVs will require a workforce trained in the technology for long-term sustainability, and the CVE project tackled this challenge directly.
VISION ELEMENT #9 Connected, Involved Citizens 	Considering the deployment of OBUs and the associated hardware and software in over 300 private participants' vehicles, combined with the strategies and campaigns to recruit and familiarize the residents of Columbus with this technology and its benefits, successfully demonstrate this vision. Involvement was further demonstrated with nearly 100% participation in the first survey conducted between December 9, 2020 and January 25, 2021, and well over 95% participation in the second survey conducted in late February 2021. And while private vehicle BSMs are not distinguishable from fleet and other vehicles, these 300-plus vehicles helped produce the one billion BSMs captured in the OS as of the end of March, further illustrating how the CVE project has engaged with Columbus residents to generate valuable data for use within the City.

VISION ELEMENT #10 **Architecture and Standards** 	Inherent in the USDOT Cooperative Agreement was the emphasis on the use of architecture – governed by rules, documentation, and standards. The CVE project clearly demonstrates the application of National ITS reference architecture, now known as the Architecture Reference for Cooperative and Intelligent Transportation (ARC-IT), as well as the extension of the project's architecture to more broad efforts in the state and region. The CVE project team regularly and consistently coordinated with DriveOhio on its deployments in Marysville and Dublin and helped establish the statewide architecture upon which all CV deployment is expected to follow. Although Smart Columbus initially implemented customization to accurately document the CVE project in SET-IT tool, later updates to the CVE project architecture documentation were able to leverage additions made to SET-IT during the timeframe of the Cooperative Agreement. The updates in both 2019 and 2020 directly covered elements of the CVE project architecture that originally required customization in the first draft that was delivered in early 2019.
VISION ELEMENT #11 **Low Cost, Efficient, Secure, and Resilient Information and Communications Technology** 	The City implemented rigorous network security design practices when architecting the physical and logical elements of the CVE. The approach isolates CVE from other critical systems while providing for both the immediate and long-term capacity needs. Advanced IPv6 capable, layer 3 network switches, deployed in multiple strategic locations, and paired with field-hardened local switches, all operating on a redundant network, ensure an efficient, secure and resilient communications backbone.
VISION ELEMENT #12 **Smart Land Use** 	CVE leveraged existing City investment in fiber infrastructure by aligning with the CTSS project, while also coordinating with the COTA bus rapid transit line (Cleveland Avenue) and key corridors relative to passenger routes (High Street), commercial activity (Morse Road) and freight (Alum Creek). The CVE project also coordinated closely with DriveOhio to ensure interoperability and consistency with long-range, regional considerations in terms of sustainability, ensuring that the infrastructure that was deployed can easily tie into other CV deployments in the state and region, both in terms of the geographic location of the corridors as well as the technology and architecture that was used. This ensures a sustainable path forward for this technology.

Source: City of Columbus

7.4.1. Conclusions

The successful deployment and launch of the CVE project was not without challenges – anticipated challenges around configuration, integration, recruitment and testing. These planned challenges had mitigations in place, mostly in the form of schedule float, and thoughtful processes and coordination for recruiting and participant engagement. Unanticipated challenges were more disruptive. The COVID-19 pandemic impacted many different aspects of the CVE project, including equipment shipment delays (for both equipment and vehicles for which installation was planned), the need for remote coordination of testing and integration activities, and the withdrawal of the local community college from workforce development plans due to a shift away from in-person classes.

Despite all of these challenges and multiple delays, the project eventually launched. The lessons learned will be applied not only within Columbus, but also throughout the state, as DriveOhio is still working toward deployment of its own CV demonstrations. Key conclusions include:

- Communications for CV and emerging technology projects were multifaceted and consistent throughout the project. This was key to the project overcoming the challenges outlined earlier. Dedicated communications staff, who engaged with each element of the program team (management, engineering/design, installation, and communications delivery staff) throughout the project ensured that communications activities were well-thought out, coordinated, and successful, as demonstrated by the relatively quick timeframe in which recruiting goals were reached, and the high survey response rates.
- The technical readiness of CV in general was below what was anticipated from the onset of the project. As described earlier in this chapter, the expectation was that the CVE project would benefit from and avoid many of the challenges identified in the earlier Safety Pilot Model Deployment and CV Pilots. Although some of these challenges (such as allowing adequate time for configuration, integration and testing) were planned for from a schedule perspective, others (such as the readiness of the applications) revealed no improvement over the past several years.
- The uncertainty of DSRC as a viable platform for CV technology remains in question. Although the administration change may advocate and support of the preservation of all 75 MHz of the spectrum, the stability of DSRC is also uncertain and may impact the sustainability of the solution as deployed. Conversion to other communication platforms or updates may be required for both the existing network and future expansion.
- A collaborative relationship with other regional CV deployment efforts required coordination but was key to interoperability and demonstrated how certain components (such as position correction and security) can be leveraged among multiple deployments.
- Although the project cannot decidedly attribute prevention of any incidents as a result of the CV technology having been installed in residents' vehicles, evidence from the analysis of the data captured from the project, coupled with anecdotal feedback from participant surveys, indicate a positive impact. Driver alerts at intersections and in school zones warned drivers of potential safety concerns. Reduced response times for fire and police created a safer community. And the outcomes of current and future data analysis can offer new insight into the location and types of potential incidents, allowing traffic engineering to be proactive in exploring future safety and mobility enhancements, all positive impacts to residents and users of the roads.

Grandmother Uses CV Technology to Keep Her and Her Granddaughter Safe on Trips to Dance Class

Tonie lives in Reynoldsburg, an eastern suburb of Columbus, and travels the Connected Vehicle Environment corridor to take her granddaughter to competitive dance lessons daily. She joined the study because she was interested in driver safety technology after experiencing a few costly fender benders. **"I quickly adapted to getting the alerts in my vehicle. There were occasions when it made me aware of things I wouldn't have noticed otherwise. I particularly liked the red light warning alert."** Tonie plans to keep the CV equipment installed in her vehicle and hopes the technology becomes more widely available. **"My granddaughter is always amused when I'm driving her to dance and we get an alert; she laughs. I take that opportunity to talk to her about driver safety, which I hope she takes with her when she becomes driving age."**

Tonie, CVE Study Participant, Reynoldsburg

7.4.2. Lessons Learned

The challenges described in **Section 7.3.2**, coupled with the successes achieved have resulted in a robust set of lessons learned. The following highlights the lessons learned, covering stakeholder relationships, communications, workforce development, technology, testing, data collection and assimilation, and operations and maintenance. These items are not listed in any specific order but are grouped into broad categories in attempt to allow quick access to specific items of interest to the reader.

- **Stakeholder relationships**
  - Continuous engagement helped circumvent possible disruption to the project plan and schedule, particularly in instances when responsible parties at key partner organizations changed.
  - The impression of a project and its leadership reflects the individuals doing the work, having either positive or negative effects. All parties acting on behalf of the project must remain cognizant of this at all times, particularly when interacting with project stakeholders.
- **Fleet installation/training/communications**
  - To maintain the overall installation schedule while ensuring that all required features were implemented, installation activities for a large portion of the fleet vehicles occurred in multiple passes, with each vehicle requiring multiple touches. For instance, certain vehicles may have been serviced four times, on four different days. First was to install the OBU, second the HUD, third to energize the system with the then current firmware, and a fourth touch to install firmware updates. The decision was made to procced in this manner to continuously advance the quantity of vehicles equipped, physical installation being the most time-consuming element of individual vehicle effort, while continuing system development and testing, at the same time. Exceptions were Fire and Police installation, given the limited ability to access those vehicles.
  - There is a benefit to leveraging existing tools for delivery of training. For the CVE project, the training approach worked well. The project training used the City of Columbus Training Portal for City staff, and existing training tools and processes at COTA, the Franklin County Engineers office, and at Dist-Trans. This allowed for a systematic approach to ensure all necessary staff were notified of and completed necessary training consistent with the approved ICD.
  - Fleet drivers may need access to a work computer to complete the survey since they may not have regular access to a computer. It is also important to work with department managers to understand what measures can be taken to increase survey response rates.
  - Video training worked well for all participants, both public and private, as it standardized what each participant received while managing the resources needed for training. It was one of the few aspects of the project that also was not impacted by COVID-19, as it supported various shifts, varying staff locations, and ever changing COVID-19-related restrictions.
  - Researchers must clearly define the information needed from each type of participant (personally identifiable information, data, survey, and training requirements) in order to develop the appropriate ICDs and determine the level of consent needed (written vs. verbal). Regularly revisiting these assignments will help ensure timely and accurate IRB submittals and approvals, which can otherwise impact project schedule since all recruitment materials and participant-facing materials need to be approved by IRB in advance of distribution.
- **Private driver recruitment**
  - A multi-channel, integrated outreach campaign is needed to achieve even modest recruitment goals. Start with shared and then earned and owned tactics, and then shift to paid last, continuing throughout recruitment.

- A well-defined email campaign to share information and remind participants to take the next steps in the process was critical to move participants successfully along to complete installation and surveys.
- Paid (radio) and owned (City of Columbus and Smart Columbus emails) tactics performed the best in this instance. Shared and earned tactics will likely perform much better when the pandemic is over, and partners and the media have more capacity.
- It can take weeks for an outreach campaign to achieve maximum efficiency. Word of mouth and referrals take time to generate but are powerful communications tactics. It is important to ensure the installation team and recruitment teams have this understanding to match installation capacity with weekly recruitment goals.
- Messaging matters: most private drivers identified with messaging and targeting that classified them as early adopters.

- Staggered and increasing incentives helped ensure continued participation in the program.
- Partnering with a trusted community organization helped to provide insight and understanding, and address potential barriers early on, particularly about privacy and security of information.

- **Installation**
  - Participants had a favorable view of Smart Columbus working with a small-business auto shop to perform installations. Participants indicated they were willing to drive up to 20 minutes to get to the installation site.
  - An auto shop that prioritizes certifications and continuing education and training is an indication of a potentially good partner. A good small-business installation partner needs to be of a certain size and capacity to meet accounting and invoicing needs of the project. This may be a barrier to participation for micro-businesses.
    - The IRB oversight of the project requires a level of understanding, customer service, and documentation that necessitates a full-time, on-site staff. Staff can be responsible for appointment reminder correspondences, informed consent and training process, recording keeping, and post-installation support.
  - Conducting the training and informed consent process online and/or prior to the participant arriving on-site for their installation would have streamlined the intake process significantly.
  - Understand the fixed costs and costs per vehicle in order to negotiate a fair contract with the small-business auto shop. It is important to factor in costs for troubleshooting and removals.
  - It was important to offer a pick-up/drop off service for participants. This increased participation and helped the small-business installer partner ensure that multiple people were not waiting on-site for hours.
- **Workforce development**
  - Solidifying an education partner (community college or trade school) to identify a pool of potential candidates would have been preferable to an open-interview process. COVID-19 made it difficult to advance early conversations with the local community college.
  - Recruitment for candidates should be a joint effort between the installation partner and Smart Columbus and requires time (four to six weeks) to adequately promote.
  - A placement component to assist technicians-in-training to find continued work after the training would be a meaningful addition to the project, particularly with larger-scale deployments.

  - It is preferred to offer the training and placement back-to-back, rather than training then placement a few weeks later. This will help with retention of technicians-in-training.

- **System and unit testing**
  - Regression testing of the full system was necessary each time there was change to any of the components. While unit and component testing was important, it did not eliminate the need to revalidate prior tests upon changes to system components.
  - Variance in GPS accuracy during certain times of the day resulted in challenges related to repeatable application behavior, requiring adjustment to the application configuration to better fit the accuracy seen in this region.
  - With the necessary access levels, and with minimal but informed local on-the-ground support, it is possible to perform a large portion of integration testing with most of the team remote, using virtual meeting tools. Planning for remote support is different than that of local, and it is not as efficient as on-site, so it must be accommodated in the schedule.
- **Data collection/analysis**
  - The volume of data captured during the operational period resulted in lengthy query run-times. Implementing methods to bin the data before processing have helped reduce run-times.
  - No issues were encountered with data structures, but minor conversion issues related to units, data types, etc. arose that had to be addressed before data could be used properly. This is evidence of the importance of standards.
  - In terms of performance measures, the approach necessary to determine if in-vehicle warnings were indicated required more processing time than was originally expected as this approach using the data in the OS required multistep algorithms. Enhancements to the OS were required to support these complex analyses.
- **Network infrastructure**
  - Obtaining personnel with IPv6 experience required going to external consultant support.
  - Even with consultant support, there was significant effort to design, configure, operate and maintain the supporting infrastructure, with troubleshooting required for errors and outages which was at times more reactive than desired.
- **RSUs**
  - Despite standards existing for RSUs, there were several subtle but important differences between vendor implementations. These ranged from deployment-critical, such as the differences in the Simple Network Management Protocol (SNMP) implementation and the ability to manage devices from a single console application, (CMCC); to something as simple as the visibility of the status indicator bulbs on the exterior of the RSU. Somewhere between those fell observations such as the differences in how a Wave Service Advertisement (WSA) was implemented, and standard Provider Service ID (PSID) assignment.
- **OBUs**
  - No standards existed for performing firmware updates using DSRC, and each of the CV Pilot sites developed unique approaches to implement this feature. This left the PMO to develop its own solution, which was implemented using a secure IPv6 connection, allowing any OBU vendor to connect to their respective remote service, providing a scalable, non-proprietary solution.

  - OBUs could not dynamically switch between using built-in GPS correction features and external GPS correction assistance services. If the OBU was configured to use the external Radio Technical Commission for Maritime (RTCM) GPS correction data, internal corrections were disabled, resulting in poor position determination when the OBU was outside of the range of RTCM transmissions.
  - To achieve compliance with the system requirements, and as an outcome of hardware integration and testing activities, select firmware and hardware anomalies/features had to be addressed. Reducing power draw in the non-operational state was the highest priority, followed by HUD brightness levels and voltage levels for the physical input/outputs.
- **CV applications**
  - Despite being assessed as TRL level 6 or higher, hundreds of hours of integration testing were still required to fine-tune and validate the full set of CV applications. Inconsistent GPS accuracy impacts of the local terrain/radio frequency environment, and antenna placement required repeated testing and adjustments to obtain consistent, acceptable application performance.
  - Even though system requirements dictate standards-based messages, message content and use were subject to different implementation by different vendors. For instance, a signal request message (SRM) initiated from a transit vehicle includes attributes, such as door open and vehicle stopped. The OBU vendor assumed roadside logic would evaluate these attributes and determine if the vehicle is stopped for loading, and if so, ignore further priority request. The RSU integrator assumed however that a stopped vehicle would suspend SRM requests until resuming travel, and as such, the RSU did not need to interrogate the SRM content. Resolution required firmware changes on both platforms.
- **CVE security**
  - Much work remains on what is the correct way to implement the electronic certificates, required to validate the authenticity of message exchanged between devices in the CVE, including use of pseudo vs. application certificates, consistency in the point in the generation/transmission process where a message is signed or authenticated, misbehavior detection and reporting, and others. Upon verification of hardware and CV applications, additional rounds of testing and firmware updates, with the certificate vendor engaged, were required to achieve the necessary interoperability and performance.

7.4.3. Recommendations

- Decision makers within stakeholder groups can change over the course of a multiyear project such as the CVE project, and with these changes comes a need to reacquaint and reaffirm commitments by the stakeholder. These changes can occur without prior notification to the lead agency. As such, it is important to maintain frequent communications between the lead agency and stakeholders, either by phone or by email, not just when a need or action is imminent, but so that the lead agency is able maintain the momentum already generated on a project with minimal to no disruption.
- Testing should accommodate not only user acceptance and operational scenarios but also confirmation of necessary data collection and analysis procedures. In the CVE project, there was limited ability to determine if any data were missing, as there is no definitive way to determine the health and status of in-vehicle systems once deployed. Testing to satisfy this need should include controlled test cases to confirm end-to-end data capture for specific vehicle classes – for the CVE, this would include a ground truth with data in the OS.

- Similarly, regarding data collection, data de-duplication must be robust, as the same message may be heard by multiple RSUs, and the number of simultaneous listeners varies from location to location and device to device. Ensuring duplicate items are not double counted can be resource intensive.

- Each part of the system is highly dependent on the system. Testing individual components separately outside of the system offers only limited confidence that the full system will operate as expected. Rigorous regression testing is a must to ensure all elements are operational.
- Network setup and configuration should consider potential rework and revision, even when it is leveraging existing infrastructure. For example:
  - Not all internet service providers provide commercial IPv6 addresses, so it may require switching to a different service provider.
  - Edge devices must be thoroughly vetted to ensure dual stack support (IPv4/IPv6) and it is recommended that all devices be on the same firmware revision to reduce possible sources of error.
  - Network Storms are possible when multiple pathways for network traffic are possible through a single device or combination of devices. In the case of the CVE network, multiple pathways were unintentionally created as part of the initial configuration of the connected vehicle co-processor CVCP (message handler software). These pathways were not discovered during lab testing, and it was not until multiple devices were deployed in the field, that the problem was discovered and resolved.
  - Ensure device configurations can be saved either directly or via controlled reboot; otherwise, settings may be lost from power-failure.
  - Plan for and allow sufficient staff time to provide secure, remote access and application permissions for integrators. For the CVE project, changes to firewall rules required approval process, as did use of applications like PuTTY[77]. It may also require exceptions to policy, which could require further staff time.
  - Testing of all fiber, whether new or existing, should be completed using accepted test practices. Do not assume prior tested fiber is functional.
- **Communications** – There are many recommendations regarding communications based on the successes of the CVE project in Columbus. Key recommendations include:
  - Build the appropriate team with necessary skill sets and availability to meet the demands of the project. The CVE project team used staff to support appointment reminder correspondences, informed consent and training process, recording keeping, and post-installation support while also using text and email for appointment reminders and participant communication. Similarly, participants would have benefited from an installation partner that could accommodate evening and Saturday installation appointments to ensure participation by a diverse group of residents.
  - Map out the customer journey (from initial interest to OBU installation) and simplify it as much as possible to increase participation.
  - Incentivize participation incrementally throughout the process commensurate with the level of effort required to participate.

[77] https://www.putty.org/

    - Provide a referral incentive for participants who have installed already as well as for people who did not qualify.
    - The type of incentive matters: Use a reward card vendor who does not charge fees per card, allows virtual reward cards to be redeemed online or in-store, and offers a Visa/Mastercard option so participants are not required to pick a specific store to redeem their incentive.
- For wider adoption, build relationships early to partner with large and medium employers, businesses, or organizations along the corridor to gain buy-in and agreement to promote the project to their employees or customers. Be prepared to create the promotional tools they will need to meet the needs of their organization.
- Create an experiential activity to boost participation such as virtual reality, augmented reality, or driving demonstrations that can be implemented at community events.
- Pop-up installation events could be a tool to increase visibility of the project, leverage other community events, and increase participation for key demographics.

7.5. SUMMARY

Ultimately, after overcoming the unplanned disruptions, the CVE project overall was successful in installing and evaluating the impact of CV technology, as assessed from the data of over 1,000 vehicles and 85 roadside locations, with billions of rows of collected CV data, and direct participant feedback from hundreds of survey results. When coupled with the available set of detailed systems engineering, deployment and test documentation, and lessons learned from a reduced-spectrum deployment, the Smart Columbus CVE is a valuable resource for future deployers, both OEM and agency alike.

The City will continue to operate and maintain the CVE with the support of the RSU and OBU vendors following the conclusion of the Cooperative Agreement, collecting data and monitoring use cases similar to what has been defined in the performance measure indicators.

Chapter 8. Multimodal Trip Planning Application and Common Payment System

8.1. PROJECT OVERVIEW

The Multimodal Trip Planning Application (MMTPA)/Common Payment System (CPS) project was designed to allow travelers throughout Columbus and outlying communities to create multimodal trips and pay for services using a single, account-based system linked to different payment media and modes of transportation. Prior to the MMTPA/CPS project, Columbus residents and visitors did not have access to a single system that allows for the seamless planning and payment for multimodal trips. The resulting mobile app was branded “Pivot” as Columbus sought to become a facilitator for Mobility as a Service by providing a platform that integrates end-to-end trip planning, booking, electronic ticketing, and payment services across all modes of transportation, public or private. The desired outcome was to make its communities work more effectively, and to improve access to jobs and job centers in the region for communities in need of travel options. Multimodal trip options include walking, public transit (Central Ohio Transit Authority (COTA) and Campus Area Bus Service (CABS)), ridesharing (Gohio Commute), bike-sharing (CoGo), scooters (Bird, Lime), ride-hailing (Yellow Cab, Uber, Lyft) as well as personal bikes and vehicles. **Figure 8-1** illustrates the system concept.

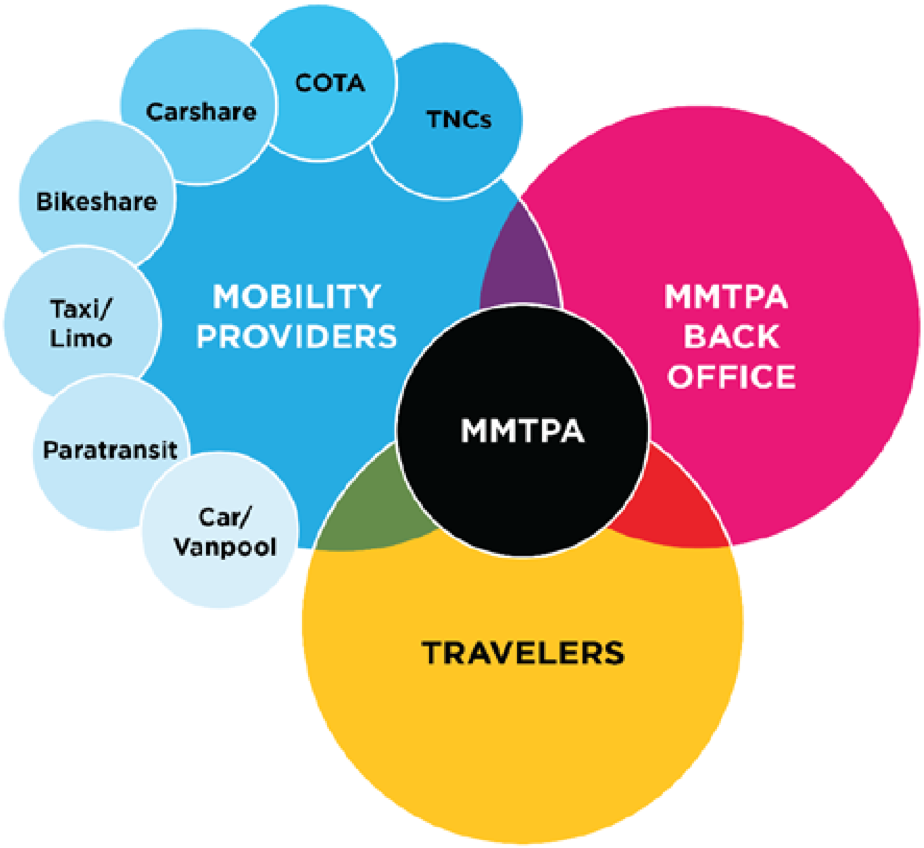


Figure 8-1: Smart Columbus Program MaaS Concept

Source: City of Columbus

The team faced several risks and challenges throughout design and development of the CPS part of the original project, which were then exacerbated by the COVID-19 pandemic. These included finalizing agreements with mobility providers for participation in CPS and finalizing the terms of participation and ownership with COTA, who had been identified as the end-owner for the solution. Development and launch, originally planned for January 2020, was initially delayed to March and then to May due to legal and business decision challenges faced by mobility providers. In July 2020, the City recommended discontinuing the CPS component of the project, with only the MMTPA component moving forward. After coordination with U.S. Department of Transportation (USDOT), this request was approved in August 2020 and a subsequent reduction in scope as well as federal and cost share reductions were negotiated.

The resulting project, known as Pivot, makes multimodal travel options easily accessible by providing a robust set of transportation and payment options even without CPS integration. Pivot allows travelers to request and view multiple trip itineraries from within a single app, and book and pay for services through deep linking[78] with various mobility provider apps. Users can compare travel options across modes, and plan and pay for their travel based upon current traffic conditions and availability of services.

[78] *Deep linking provides users the ability to link directly from the Pivot app to content in mobility provider apps. Trip information is sent to mobility provider apps for payment and trip execution. If the apps are not already installed on users' smartphones, users are prompted to download from the appropriate app store.*

The Pivot app uses a foundation of open-source and proven technologies. There are no dependencies on subscription services, proprietary code, or commercially licensed data. The platform is made of containerized microservices, which allow for interoperability with the Smart Columbus Operating System (SCOS) or another future host environment. The custom code can be entirely redistributed as MIT-licensed, open-source software, if desired. The platform includes a distributed ledger ("blockchain") that offers redundancy, transparency, shared governance, and long-term viability for Columbus and other cities who decide to deploy the platform to address similar gaps in service as identified above. **Figure 8-2** contains screen shots from the Pivot app.

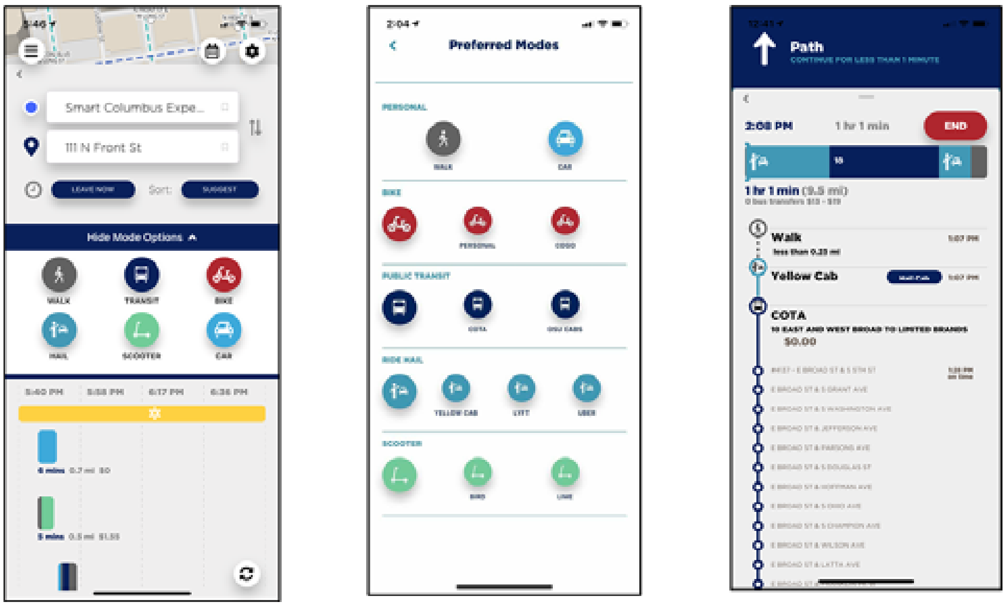


Figure 8-2: Pivot App

Source: City of Columbus

8.2. DEPLOYMENT SUMMARY

The Pivot app offers real-time mobility options for users in the Columbus region. Current participating mobility providers include: COTA, CABS, Yellow Cab of Columbus, CoGo bike-share, Lime, Bird, Lyft, Uber and Gohio Commute. Users are able to see nearby ride options for bus, scooter, and bike, and receive live transit alerts through the app. Pivot's many features include a sophisticated navigation system with turn-by-turn instructions, and is available on multiple platforms including Android, iOS, Smart Mobility Hub kiosks[79], and web. Anonymized trip data are transmitted to the Smart Columbus Operating System through a secure Application Programming Interface (API), allowing access to traveler behavior information that was previously inaccessible to the City.

Pivot was built on the following design principles:

- A foundation of open-source and proven technologies. There are no dependencies on subscription services, proprietary code, or commercially licensed data.
- Flexible hosting options due to the containerized open approach to development.

[79] *Smart Mobility Hubs are described in **Chapter 11**.*

- A distributed ledger ("blockchain") which offers redundancy, transparency, shared governance, and long-term viability.
- Users book trips with the assurance that their travel history and other personal information is not available to anyone, including the project team, unless they volunteer to release certain information for platform improvement or trip booking.
- Machine learning for optimized trip planning results.
- The Pivot app, website, and Smart Mobility Hub kiosk app all run the same codebase, while properly tailored for the look and feel of each device type. Smart Mobility Hubs include a free-standing kiosk that provides a user interface with Pivot. Travelers can plan and execute trips by sending trip plans from the kiosk to their smartphones to open in Pivot (**Figure 8-3**).

Figure 8-3: Pivot App on IKE Smart City Interactive Kiosk

Source: City of Columbus

8.2.1. Systems Engineering Approach

The MMTPA/CPS project was developed using a Hybrid systems engineering approach, combining V-Model and Agile development.[80] This approach began with a user-driven concept development process, which transitioned into an Agile release process after the vendor was brought on board. It was designed to mitigate risk by focusing on sprints of incremental delivery and shorter development cycles, which allowed for

[80] *Different types of systems engineering approaches are discussed in Chapter 2, Section 2.1.*

continuous feedback from the City and key stakeholders. This, in turn, enabled the project team to respond to and prioritize changes more effectively throughout the development cycle by focusing on the validated learning that comes through rapid development.

The MMTPA/CPS project team developed systems engineering documents (Concept of Operations (ConOps), System Requirements Specification (SyRS), System Architecture and Standards, and User Acceptance Test Plan and Test Report) to create the overall design and vision for the project. It should be noted that the MMTPA project pivoted to Agile development after the ConOps was drafted, whereas the CPS project went on to produce a SyRS document to refine key features, functionality and behaviors for the system. In lieu of a SyRS document, the MMTPA Request for Proposal (RFP) and vendor contract contained numbered requirements specific to the MMTPA that were directly traceable to user needs from the ConOps. The vendor teams (Etch and Bytemark) led development in sprints with the project team evaluating and testing developed functionality against the system requirements and system architecture.

Toward the end of development, a test plan was produced with test cases tracing to both the MMTPA RFP and CPS requirements and user needs in the ConOps. Due to the CPS project being removed from the Smart Columbus Program around this time, the test plan was updated to include only Pivot, and the test results report also reflected the final project structure. Existing CPS functionality in the Pivot app was replaced with an alternative approach to payment using deep linking to mobility providers' apps. After the launch of the Pivot app, the ConOps document was revised to remove CPS as well as make other changes to reflect the actual deployed system.

Figure 8-4 illustrates the MMTPA/CPS project following a standard V-Model systems engineering approach up to the point of RFP and high-level design, and then pivoting to Agile development until the system verification phase and user acceptance testing.

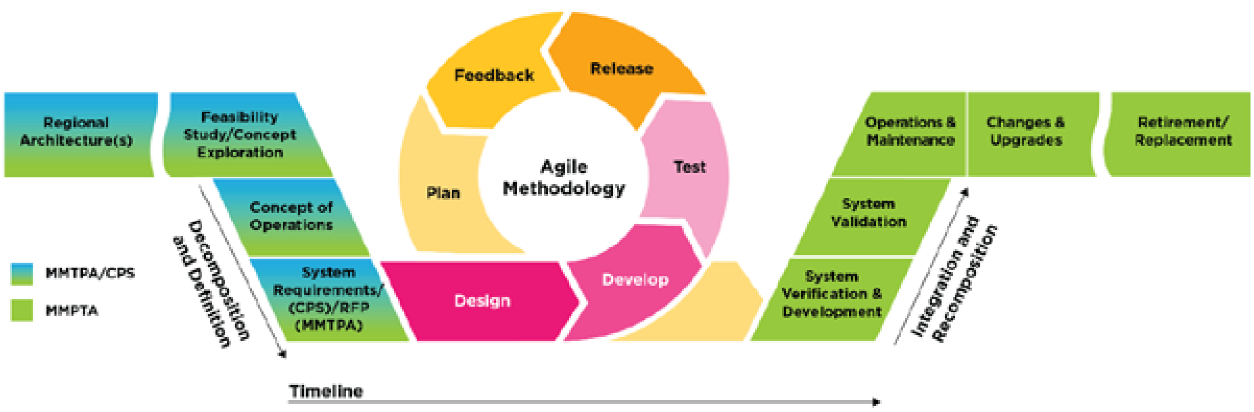


Figure 8-4: MMTPA/CPS Hybrid Systems Engineering/Agile Development Methodology

Source: City of Columbus

Throughout the Agile development process, both teams developed policy and direction regarding necessary contracts and agreements for the project, including:

- Mobility Service Provider (MSP) MMTPA Agreement
  - An information exchange and action agreement between the City and mobility providers to participate in the MMTPA project.
- City-Bytemark Merchant of Record Agreement
  - A financial agreement between Bytemark and the City in which Bytemark agrees to handle aspects related to electronic payment acceptance.

- Bytemark-MSP Sub-merchant agreement
  - An agreement between Bytemark and the mobility providers to offer financial Merchant of Record services.
- MSP CPS agreement
  - An amendment to the MSP MMTPA Agreement in which mobility providers agree to accept CPS terms and conditions and fee structure.
- IKE Smart City Operations and Maintenance Agreement
  - An agreement between the City and IKE Smart City (kiosk vendor) that covered operations and maintenance of the kiosk as well as enabled the integration of the Pivot app on the Smart Mobility Hub kiosks.
- 904 Lease Agreement
  - An agreement between the City and scooter companies (Lime, Bird, Link) to allow the installation and placement of shared mobility devices within City right-of-way and data sharing with the City.

Figure 8-5 summarizes the general timeframe for the project as it relates to these major activities.

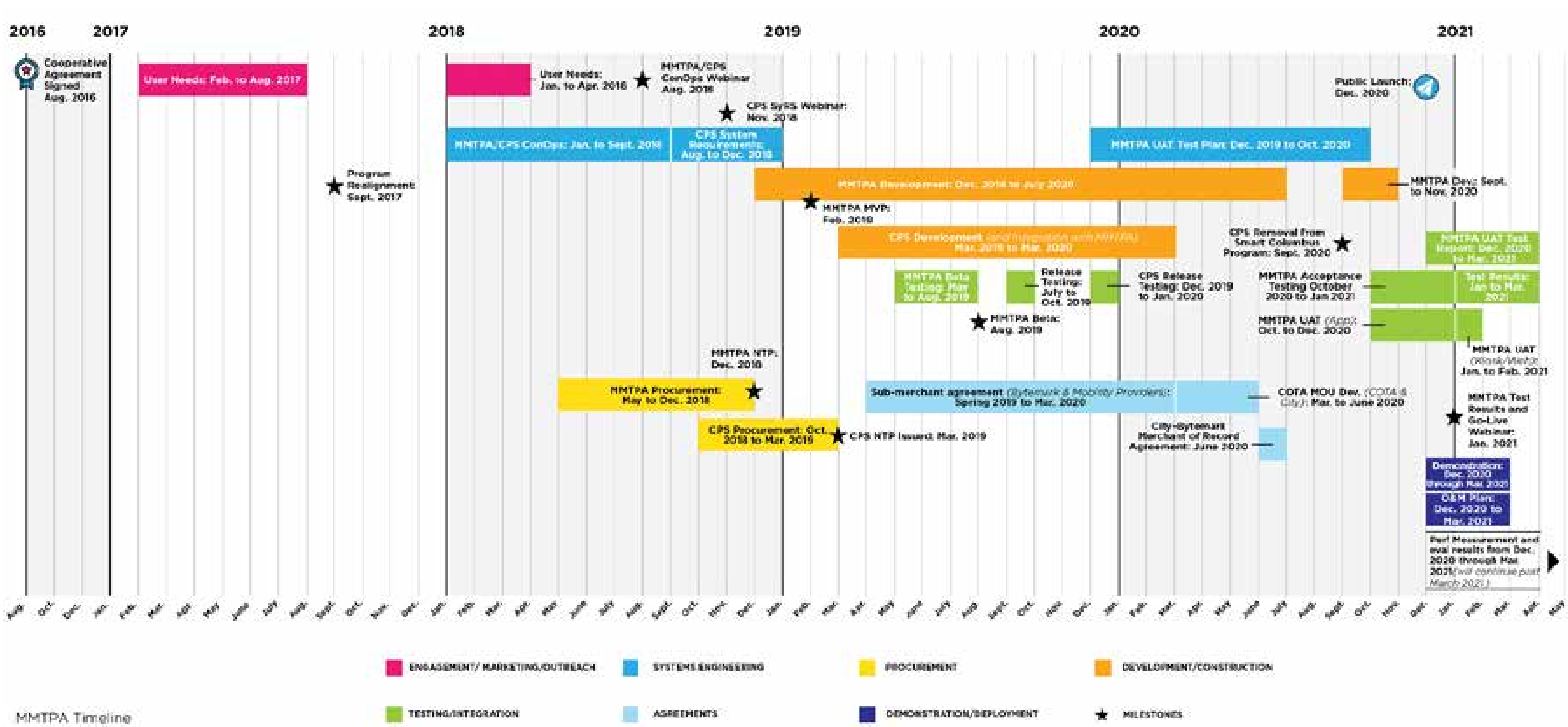


Figure 8-5. Timeline of Multimodal Trip Planning Application and Common Payment System Project

Source: City of Columbus

8.2.2. Project Launch

The launch for the MMTPA/CPS project was initially planned for early 2020; the date was dependent on finalizing the Merchant of Record agreement between the City and Bytemark. Initially set for January, the date shifted from March to May 2020 as review and negotiations continued before the onset of the pandemic in March 2020.

As described earlier in the chapter, the delays in agreements and ownership of the CPS, exacerbated by COVID-19, ultimately resulted in the removal of CPS. In September 2020, the project team transitioned to filling the gap in payment with deep linking between the Pivot app and third-party mobility provider apps. The solution required extricating CPS from the application code, implementing deep linking with the mobility providers, and incorporating registration and sign-in functionality from the CPS account into the Pivot app. With development back on track, the team focused on preparing a final release and acceptance testing for the mobile app first, followed by the web and Smart Mobility Hub kiosk testing.

Prior to launch, the communications team assisted in recruiting for focus groups and beta testers for Pivot. They also worked with COTA to develop the brand and brand identity for the app based on input from residents, and identified key stakeholders for the project and set up one-on-one meetings. Additional activities included coordination through monthly meetings to update stakeholders at the launch of Pivot at the Smart Mobility Hubs.

Figure 8-6. Pivot Focus Group

Source: City of Columbus

Pivot was launched publicly after integration of deep linking payment options via a press release and supporting videos from the Mayor, Program Manager, and Pivot users. The videos were shared and promoted on social media from the Smart Columbus Facebook page. Increased rates of COVID-19 locally and active stay-at-home advisories prevented a more interactive, community-based launch event. A website was also deployed in the weeks leading up to the Pivot launch to help steer users to download the app from app stores (known as “conversions”). Pivot advertisements were placed on Facebook, Twitter, and Google to raise awareness and promote usage.

8.2.3. Demonstration

The following information was routinely collected from the website that was deployed as part of the launch, so that the communications team could tailor specific ad content and placement to boost adoption and usage during demonstration:

- **Acquisition (app download) –** Number of downloads, including source through download
- **Registration complete –** Number of Pivot registrations
- **Linked accounts –** How many and which ones (e.g., Gohio Commute)
- **Trip planning –** User flow, start-point of abandonment or completion
- **Booking –** User flow, start-point of abandonment or completion
- **Booking location if booked by Smart Mobility Hub kiosk –** Latitude/longitude of kiosk location
- **Deep linking –** Point when user clicks on deep link option for trip plan
- **Active users (daily/weekly/monthly) –** Number of users who initiate sessions on the app within a specific period, including 1-day, 7-day, 14-day, and 28-day time periods
- **Retention –** Number of returns until abandonment. This would be the length of time a user is retained before “abandoning” app use. “Abandonment” would be defined as an extended period of inactivity, such as 1 or 2 months
- **Engagement –** Frequency of return/depth of use
- **Cohort analysis –** Users by acquisition time frame, aligned to feature releases/bug fixes

Following the launch of the Pivot app in December of 2020, the Pivot app was downloaded 1,103 times. **Table 8-1** shows overall Pivot app metrics for this period (December 9, 2020 through March 31, 2021.

Table 30: Overall App Metrics 12/9/2020 to 3/31/2021

Total Downloads	Registered Users
1,103	606

Source: City of Columbus

Data from Pivot was reported as trip segments, or how many legs there were in a single trip. For example, a trip could include multiple modes such as a personal vehicle, to bus, to scooter. Each mode used is considered a trip segment. Prior to the public launch, there were 2,354 trip segments using Release 3 of Pivot. Following the public launch, there were 970 trip segments[81] as shown in **Figure 8-7**.

[81] *https://discovery.smartcolumbusos.com/visualization/8bonx4hh (data through 3/31/21)*

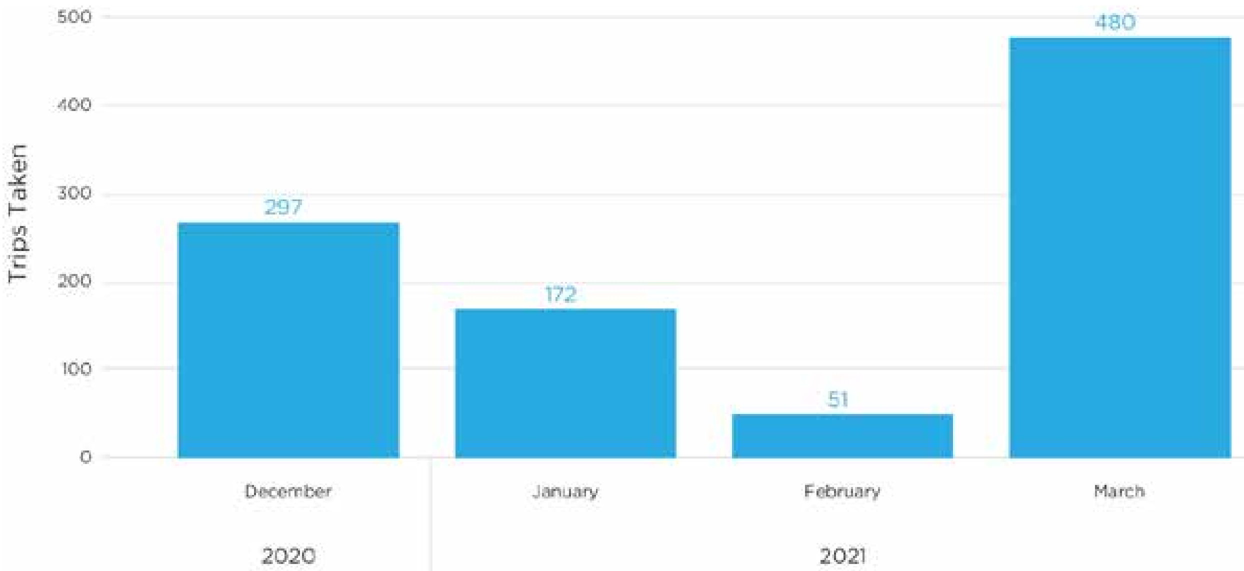


Figure 8-7: Monthly Trip Segments Booked Using Pivot

Source: City of Columbus, https://discovery.smartcolumbusos.com/visualization/g6m3biod

From September 2019 when data was ingested into the Operating System from Pivot Release 3 through March 31, 2021, Pivot users logged 5,820 miles, which is greater than the distance between the City of Columbus and its sister city Genoa, Italy (4,452 miles). As shown in **Figure 8-8**, since the official launch of Pivot, over 1,700 miles have been logged by users.

Figure 8-8: Monthly Distance Traveled Using Pivot

Source: City of Columbus, https://discovery.smartcolumbusos.com/visualization/8pnkn0kl

8.2.4. Communications

The communications goals of the MMTPA project were to:

- Raise awareness of new app
- Encourage downloads of app
- Encourage continued use of the app
- Solicit feedback from users

All these goals encouraged recruitment and app adoption.

The communications team used a multichannel communications approach, largely relying on paid digital tactics because it created a more direct customer journey to download and because of limited grassroots engagement opportunities as a result of COVID-19.

The targeting approach split central Ohioans into two broad groups: Riders and Drivers. Each group is receptive to a different type of messaging. The priority audiences were people who use public transit as their primary mode of transportation because they do not have a reliable personal transportation option (Riders), and people who have access to a personal vehicle and are accustomed to using it regularly (Drivers). By and large, Riders are current COTA users who are seeking ways to make their trips more reliable, comfortable and efficient.

Prior to the pandemic, Drivers might have been more open to experimenting with multimodal transit; however, in the age of COVID-19, this audience was likely using vehicles, where one can go from any origin to any destination with minimal health risk. The message targeted towards this audience was that Pivot offers a navigation tool built for Central Ohio by Central Ohioans that can easily replace Google Maps, Apple Maps, Waze or other navigation apps. The use of Pivot as a primary navigation app also grants this audience the flexibility to consider the region's other modes of transportation in select circumstances. Finally, this audience in particular might respond positively to the opportunity to be part of the program and shape the future of mobility in central Ohio.

Messaging themes were developed around the goal of communicating Pivot's features and values to individuals who are likely to adopt a multimodal navigation app (Riders) and to individuals whose adoption of the app can make their day-to-day lives easier (Drivers).

Research demonstrates that vehicle ownership and costs associated with vehicle ownership are common factors which affect transit ridership. Possessing a driver's license and owning a vehicle generally decreases a person's likelihood of relying on public transit.[82] Increases in household vehicle availability explains up to 62% of the recent decline in transit ridership.[83] However, high gasoline prices and high parking fees increase the likelihood that an individual will use alternative methods of transportation.[84]

Multiple sociodemographic factors predict transit use. Low earners are overrepresented among transit riders. As of 2017, individuals from households earning less than $15,000 annually comprised 21% of public transit riders, but individuals from that income bracket comprised only 13% of the U.S. population.[85]

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[82] *Congressional Research Service. 2018.*

[83] *Lehmann. 2018.*

[84] *Agarwal & Collins. 2016.*

[85] *American Transportation Association. Who Rides Public Transportation: The Backbone of a Multimodal Lifestyle. 2017. https://www.apta.com/wp-content/uploads/Resources/resources/reportsandpublications/Documents/APTA-Who-Rides-Public-Transportation-2017.pdf*

Communities of color make up the largest share of public transit riders (60%), with African Americans comprising the largest single group (24%) within communities of color.[86]

To better understand the Rider and Driver audiences, the communications team examined U.S. Census and USDOT data for neighborhoods throughout Columbus to better understand the demographic, socioeconomic, and transit ridership characteristics of each neighborhood. These data were incorporated into an interactive dashboard using Power BI software, which enabled detailed analysis of each census tract in the Columbus metro area. Data for each census tract were summarized to better inform the Riders and Drivers message strategy. Individuals who are Drivers are likely familiar with mobility apps such as Uber or Lyft, but they rely primarily on personal vehicles for their daily travel. These individuals tend to be more affluent than Riders.

The key messages developed to reach these audiences included:

- Pivot, central Ohio's navigation app, is locally designed to optimize movement around the region using the area's unique mix of transit options like COTA bus, ride-hailing, carpool, bikes, scooters, taxis and even individually owned cars.
- Pivot is a new navigation app built in central Ohio for central Ohioans.
- Pivot optimizes routes based on personal needs and preferences.
- Payment is seamless in Pivot.
- Pivot providers are taking significant measures to promote the health and safety of their riders during these unprecedented times.
- Pivot offers complete flexibility whether you are driving your car or looking for a nearby bike or scooter.
- Pivot grants central Ohioans the opportunity to shape the future of mobility in our community.

Prior to launch, the communications team assisted in recruiting focus groups and beta testers for the app. They also worked with COTA to develop the brand and brand identity for the app based on input from residents. Because the role of community leaders and local government is particularly important in diverse, urban communities, it was important to first educate and gain the buy-in of neighborhood influencers. One-on-one virtual meetings with these local influencers provided an opportunity to tout the benefits of the app and the Smart Mobility Hubs, and to answer any questions they had. Because COVID-19 prohibited the ability to engage with large crowds to promote the programs, it was helpful to learn from local leaders how they were keeping in contact with their constituents and neighbors. This strategy proved beneficial as local leaders were willing to amplify the Pivot app and closest Smart Mobility Hub on their communications channels. The Smart Columbus Program provided turnkey content to partners (social media posts, imagery, FAQs, printed materials, blog posts, e-newsletter copy, etc.) to share information on the projects, which was greatly appreciated by the leaders.

Audience segmentation, messaging, and strategy continued to evolve as the project evolved. After the project team removed CPS, the communications team could finalize the communications plan and prepare for launch. Between the launch on December 9, 2020, and the end of the demonstration on March 31, 2021, the team deployed a variety of outreach tactics, described below (a description of the paid, earned, owned and shared tactics is provided in **Chapter 3, Section 3.2.3**).

[86] *American Transportation Association. Who Rides Public Transportation: The Backbone of a Multimodal Lifestyle. 2017. https://www.apta.com/wp-content/uploads/Resources/resources/reportsandpublications/Documents/APTA-Who-Rides-Public-Transportation-2017.pdf*

8.2.4.1. PAID

- Digital Ads
  - Google (display and search)
  - Facebook, Instagram, Twitter
    Nextdoor and YouTube apps **(Figure 8-9)**
  - WOSU (local public radio) newsletter and website
  - CD 92.9 (locally-owned alternative music station) website
  - LaMega (Spanish-language radio) website
  - Sponsored content in newsletter, Facebook Live, article, and social media posts from ColumbusUnderground
- Radio Ads
  - Radio One – 1,120 spots for 16 weeks
  - La Mega – 644 spots for 16 weeks **(Figure 8-10)**
  - WOSU – 337 spots for eight weeks
  - CD 92.9 – 456 spots for eight weeks

Figure 8-9: Pivot Twitter Ad

Source: City of Columbus

Figure 8-10: Digital Ad for Pivot on LaMega's Website

Source: City of Columbus

- Print Ad (Figure 8-11)
  - *Columbus African American News Journal* (three ads), 40,000+ monthly circulation

Figure 8-11: Targeted Pivot Ad in Columbus Newspaper

Source: City of Columbus

8.2.4.2. EARNED

- Press release with video announcement
- Covered by Columbus Dispatch, Columbus Underground, and local television station

8.2.4.3. OWNED

- Website launch (https://pivotcolumbus.com/)
- Webpage updates on the Smart Columbus website
- Organic social media posts from Smart Columbus accounts on Facebook, Twitter and Instagram

8.2.4.4. SHARED

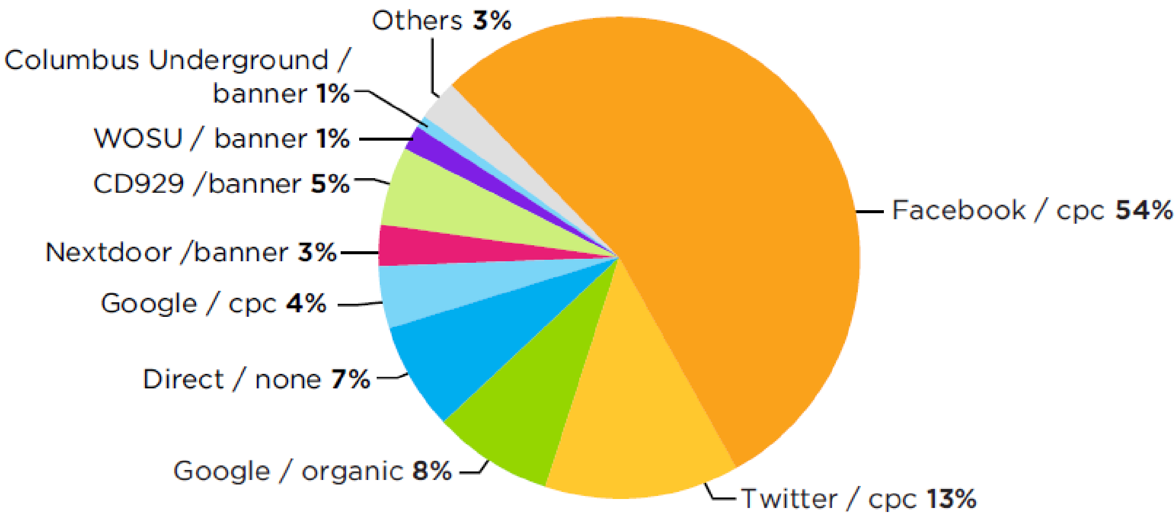
- Toolkit distribution to stakeholders (Columbus Metropolitan Library, St. Stephen's Community House, Columbus Department of Neighborhoods, Columbus Department of Recreation and Parks, Columbus Area Commissions)
  - Included sample social media posts, images, newsletter copy, FAQ, and talking points
- Social media posts/promotion from mobility partners
- Columbus Yellow Cab

After launch, the communications team also promoted the in-app survey as part of the digital campaign. Budget was dedicated to a specific ad set encouraging people to download the app, create an account, book a trip, and respond to the in-app survey to earn a $25 reward card. The communications team also supported sending email reminders to users who qualified for the survey but did not take it immediately after ending their trip. Data were tracked for the website and **Table 8-2** shows overall Pivot app metrics for the period from December 18, 2020, through March 31, 2021. **Figure 8-12** provides website traffic information by source, and sessions by source type.

Table 31: Website Analytics, 12/18/2020-3/31/2021

Users	Sessions	Engaged Sessions	Engagement Rate	Conversions
13,069	15,242	2,469	16.2%	793

Source: City of Columbus



Source / Medium	Sessions	%
Facebook / cpc	8,008	54%
Twitter / cpc	1,915	13%
google / organic	1,184	8%
(direct) / (none)	1,047	7%
google / cpc	626	4%
Nextdoor / banner	392	3%
CD929 / banner	799	5%
WOSU / banner	215	1%
Columbus_Underground / banner	166	1%
Others	371	3%
Total Sessions	**14,723**	**100%**

Figure 8-12: Website Traffic by Source: Sessions by Source Type

Source: City of Columbus

Figure 8-13: Pivot Website Homepage

Source: City of Columbus

Based on the engagement rate to feature-specific messaging through the digital campaign, the features and functions that appealed most to the Rider audience were:

- Real-time bus information and route warnings, bike/scooter affordability, sort trip options by fastest and cheapest, increased safety with comprehensive trip planning, seamless payment processes and more.

And the features and functions that appealed most to the Driver audience were:

- Turn-by-turn directions informed by local traffic and other data, seamless payment integration with ride hailing, scooter and bike share apps, ability to use scooter/bike share when navigating high density areas instead of being reliant on a car.

In terms of visibility, Facebook and Instagram provided optimal conditions in terms of numbers of users reached, frequency of their exposure to the message, as well as creative flexibility. The ability to use multiple ad formats allowed the team to single out the best performing ones (videos), as well as quickly adjust copy to users' engagement to different messages. Together, those channels drove 16,546 Link Clicks, 574 Post Reactions, 199 Conversions, and 68 Post Shares.

From an app install perspective, Google App Campaigns have been generating the most volume and have the best install rate, which points to high relevance of Pivot app campaign ads for the target audiences. Together, those campaigns drove 97,196 Impressions, 2,165 Clicks, and 69 Conversions.

Given the higher costs and lower than average engagement, Twitter performance was subpar. Video and card ad formats produced better results, while app ads were significantly more expensive (ten times the cost per install of Android app ads on Google).

Smart Columbus' strategy to engage the local community using multiple targeted touch points was well-received and helped deliver additional app downloads. The media partnerships were particularly important for generating brand awareness, and local influencers were important for validating and helping to drive downloads. Targeted outreach to specific areas of the City in both English and Spanish was critical to reaching audiences in a culturally and linguistically responsive manner. While there is no substitute for engagement at live community events, the Smart Columbus team was still able to successfully shift to a virtual engagement strategy.

Given the results of the campaign, the communications team recommends:

- Maintaining a channel mix that brings awareness to all demographics
- Focusing conversion campaigns toward younger demographics of both riders and drivers
- Continuing app campaigns on Google and Facebook, given their efficiency in generating installs and the relatively low cost
- Using video creatives for all message pillars to maximize user engagement, and to highlight app features in communication
- Expand the variety of creative communication tools to support a long-term communication plan which avoids ad and message fatigue or refresh the creative approach periodically

8.2.5. Project Costs

Table 8-3 and the figures below illustrate the costs of deployment and operations for Pivot during the Cooperative Agreement, as well as by vendors who supported this work. Deployment covers the time from project beginning to launch on December 19, 2020. Operations covers the launch until the end of the demonstration period.

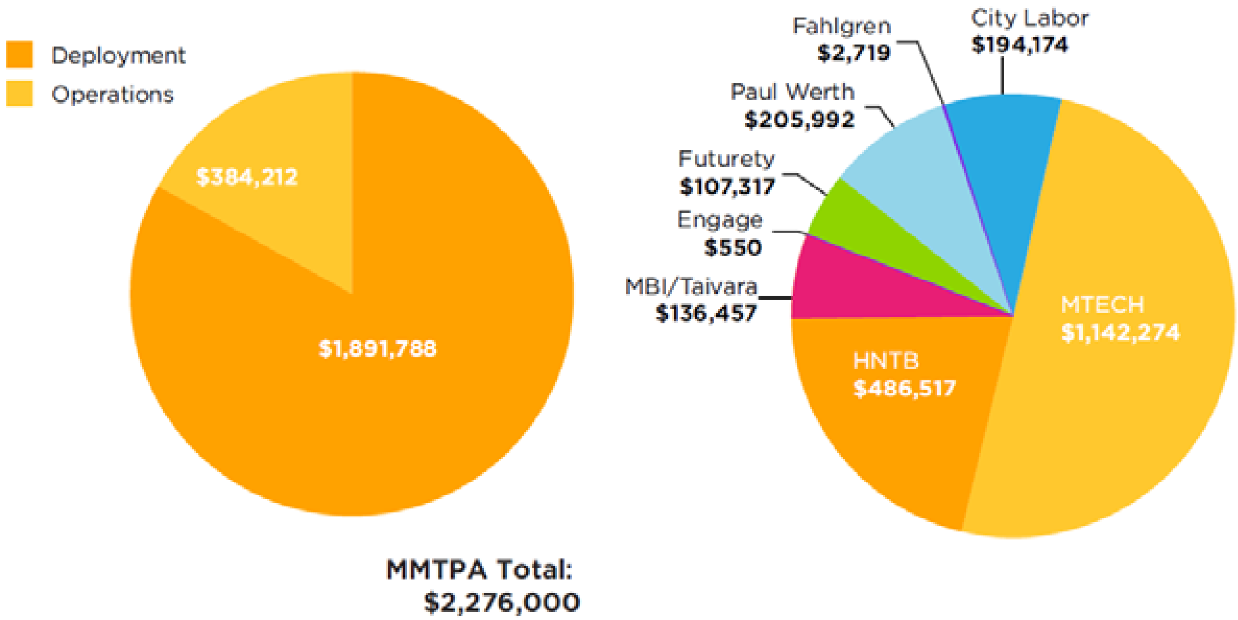


Table 32: Deployment and Operations Costs of Multimodal Trip Planning Application Project

MMTPA Vendor Actuals	Deployment	Operations	TOTAL
MTECH	$1,122,576	$19,698	$1,142,274
HNTB (WSP)	$366,283	$120,234	$486,517
MBI (Taivara)	$53,124	$83,333	$136,457
Engage (MurphyEpson)	$550	-	$550
Futurety	$78,292	$29,025	$107,317

MMTPA Vendor Actuals	Deployment	Operations	TOTAL
Paul Werth	$137,218	$68,774	$205,992
Fahlgren	$2,563	$156	$2,719
City Labor	$131,182	$62,992	$194,174
TOTAL	$1,891,788	$384,212	$2,276,000

Source: City of Columbus

The costs shown in **Table 8-4** are considered part of the “Removed Projects” category from the budget information presented in **Chapter 3**. The CPS project was discontinued before moving into the operations phase, therefore all costs in the table below are program-related deployment costs.

Table 33: CPS Project Costs

CPS Vendor Actuals	Deployment
Siemens (Bytemark)	$1,470,960
City Labor	$114,235
TOTAL	$1,585,195

Source: City of Columbus

Table 8-5 provides the Pivot app’s recurring costs, and the party responsible for each cost related to Operation and Maintenance of the system after the demonstration period.

The City has allocated funds beyond the Cooperative Agreement to operate, maintain, and enhance the Pivot app through January 2022. Future budget allocation for operations, maintenance, and enhancements will be reassessed during Q3/Q4 of 2021. During this period, sustainability and end-of-life replacement will be reviewed by the Program Manager and Deputy Program Manager.

Table 34: Pivot App One-Time and Recurring Costs After Demonstration

Description	Cost	Responsible Party	Comments
Ÿ Pivot app ongoing development (enhancements as identified and prioritized) Ÿ Data reporting analytics Ÿ COTA integration Ÿ Web portal and Smart Mobility Hub kiosk enhancements	$100,000	Etch	One-time cost for enhancement and development, including integrating with other mobility providers as they come on board.
Ÿ Hosting fees Ÿ Support Ÿ General maintenance	$10,000	Etch	Recurring cost (annual) for Amazon Web Service (AWS) hosting fees, general maintenance, and operations of the Pivot app.

Source: City of Columbus, Etch

8.2.6. Project Stakeholders

Each project was led by the City, with vendor support playing a critical role in implementation. Vendors were primarily responsible for planning, documentation, testing and integration, and delivery of system functionality. For the MMTPA project, these vendors and their roles are summarized in **Table 8-6**, with sub-contractors in parentheses.

Table 35: MMTPA Project Vendor Responsibilities

Vendor	Role/Responsibility
Etch (Lextant, ms consultants)	Pivot developer
HNTB (WSP)	Systems engineering documentation, Cooperative Agreement deliverables, testing
Michael Baker International (Taivara)	Testing
Engage (Murphy Epson)	Outreach and engagement
Futurety	Recruiting and adoption
Paul Werth (The Saunders Company)	Recruiting and adoption

Source: City of Columbus

While the project team worked throughout the Cooperative Agreement to develop, deliver, operate, and maintain the MMTPA project, stakeholders played a critical role in the process. **Table 8-7** summarizes the specific stakeholders that were engaged, as there were many diverse groups that came together to make the project successful. This table serves to highlight their contributions by categorizing them into three areas to indicate when their participation was used:

- **Systems Engineering –** These organizations/groups contributed to defining end-user needs, ConOps or system requirements documentation.
- **Development –** These organizations/groups contributed to the build out of the project. This includes installation, integration, testing, and recruitment/outreach planning.
- **Demonstration –** These organizations/groups contributed to the operations and maintenance of the project from go-live to end of the demonstration.

Table 36: Project Stakeholders

Stakeholders	Systems Engineering	Development	Demonstration
Community Based Organization			
Linden Residents	X	X	
Linden Liaisons	X	X	X
Easton Workers and Visitors	X	X	
Linden Resident Focus Group		X	
Downtown Commuter Focus Group		X	

Stakeholders	Systems Engineering	Development	Demonstration
Educational			
Columbus State Community College (CSCC)	X	X	
Ohio State University (OSU)		X	X
Government			
Mid-Ohio Regional Planning Commission (MORPC)	X	X	X
ODOT	X	X	
USDOT	X	X	X
COTA	X	X	X
Experience Columbus	X	X	
City of Columbus Department of Recreation and Parks	X	X	
City of Columbus Department of Technology	X	X	
City of Columbus Department of Public Service	X	X	
Private Entity			
SPX/Genfare	X	X	
Ford/Greenfield Labs	X		
RideAmigos		X	
Mobility Provider			
Lyft		X	X
Yellow Cab		X	X
CoGo bikeshare		X	X
Uber		X	X
Lime		X	X
Bird		X	X
Tourism			
Friends of Columbus			X
Transit Advocates	X		X
Downtown Special Improvement District (SID)		X	X

Source: City of Columbus

8.3. PROJECT EVOLUTION

This section details how the MMTPA/CPS project evolved from its conception during the development phase, through the systems engineering process and ultimately to deployment.

8.3.1. Scope Changes

8.3.1.1. CPS AND THE SMART COLUMBUS WALLET

The CPS project had risks and challenges that the team was already working actively to mitigate when COVID-19 exacerbated these issues. This specifically included finalizing agreements with mobility providers for participation in CPS, and ensuring that the terms of agreement with Bytemark were highly amenable to COTA as future owner of the solution. Development and launch, originally planned for January 2020, had already been delayed until March and then May due to these legal and business decision challenges from mobility providers. Then negotiations stalled completely because of the pandemic. In addition, like other transit agencies in the pandemic, COTA ridership dropped 50% in the first two weeks of the pandemic and remained at low levels through the demonstration. Through the course of working with the City on the MMTPA/CPS project, COTA became aware of the challenges and limitations of its existing fare collection system upgrade, which entailed replacing all fare boxes on its coaches, and installing on-board validators, as well as permitting cashless transactions and providing users with account-based mobile ticketing. Numerous schedule delays and technical issues led to the issuance of an RFP in July 2020 to replace the existing fare collection equipment and re-architect its approach to account-based, multimodal fare collection using a more scalable open architecture capable of accepting a variety of payments to support next generation fare payment technology. The new system will be capable of plugging into multiple trip planning solutions.

The removal of CPS from the Smart Columbus Program was the most significant change in the project. This was caused by challenges finalizing agreements with mobility providers for participation in CPS, issues with COTA's existing fare collection system, finalizing the terms of ownership with COTA, and COVID-19 impacts on COTA and private mobility service providers. Until the pandemic, COTA had been prepared to assume ownership and had agreed to the transaction fee structure established for CPS. However, as the pandemic hit, COTA found itself unable to assume this responsibility due to losses in ridership/revenue and inability to sustain the resources necessary to operate and maintain the system.

Additional impacts of removal of CPS from the Smart Columbus Program include:

- The loss of ability to purchase and pay for COTA trips within the Pivot app, as this functionality was directly tied to APIs between Bytemark's back office and Genfare (COTA's fare management system provider). Removal of CPS required that user account creation and management be incorporated into the Pivot app. COTA remained fare free through January 10, 2021, so complete "paid" trips could include COTA trips completed through this date.
- The loss of CPS integration with the Event Parking Management (EPM) project via the Smart Columbus wallet to pay for parking. Integration between the two systems was already underway at the time when CPS was removed from the program.
- Required reevaluation of payment to ensure the success of the Pivot app. The City coordinated with mobility service providers to develop a payment solution, which led to deep linking with mobility providers. Deep linking allows the traveler to pay for trips directly through the mobility provider's app; however, this was implemented at the expense of the City's goal of creating a common payment wallet. It is our understanding that COTA's future fare management solution will meet the City's and region's common payment goal through specific integration with mobility providers.

8.3.1.2. EMERGENCE OF SCOOTERS

The sudden emergence of electric scooters in Columbus was not anticipated during the ConOps and scoping process for the MMTPA/CPS project. The scope of the MMTPA project was widened following their arrival to accommodate this new mode within the Pivot app. The app designer, Etch, had to develop a new solution for scooters in Open Trip Planner (OTP). The team provided navigation that followed sidewalk and right of way ordinances – this meant combining geographic information systems (GIS) data in Open Street Map with the trip routing in OTP. The benefit of using OTP is that the code from this effort was then shared back to the community for use in other applications.

8.3.1.3. DISAPPEARANCE OF CAR-SHARING PROVIDER

The MMPTA ConOps was written when car-sharing service providers in Columbus were more active than today. Car2go was the first carshare provider in Columbus, entering the market in October 2013; however, it exited in May 2018. Zipcar entered Columbus in June 2018, and announced a partnership with the City to provide on-demand access to area residents, businesses, visitors, and students. However, Zipcar did not believe that joining Pivot worked well with its business model, particularly since Zipcar uses an A-A trip model (i.e. round-trip) where the vehicle is returned to the origin of the trip.

8.3.1.4. INTERACTIVE VOICE RESPONSE

An Interactive Voice Response (IVR) system was proposed to be part of the MMTPA project so travelers could initiate trips or modes via a phone call, and without requiring a smartphone. However, it became evident that most mobility providers required a smartphone anyway to unlock a device or use the mode. There was a consideration of using the Interactive Kiosks (IKs) in Columbus to initiate trip legs, but the IKs do not have phone access although they do have an emergency call button. A mitigation was proposed to include the IVR phone number on the IK for users to call, but the IVR was ultimately removed from the MMTPA project. Instead, users can plan a trip in the IK, receive the trip plan by text or email on their smartphones, and execute the trip using the Pivot app.

8.3.1.5. OPERATING SYSTEM INTEGRATION

The requirement for the Pivot routing engine (trip optimization) to reside in the Operating System was de-prioritized during Agile development, and currently resides in the Etch back-office (AWS cloud-hosted environment). Migration of the routing engine from the Etch back-office to the Operating System will be reevaluated after the demonstration period. Because of the containerized approach to developing the Pivot solution, it is possible for all or some of the platform components to be hosted on other cloud-based systems, or a combination of networks, as necessary.

8.3.1.6. SHARED ACCOUNT LEDGER AND PAYMENT BROKER

COTA's decision not to participate in the CPS shared account ledger (a distributed ledger system using blockchain) early in the development process impacted system architecture for the project by eliminating the reason for an open-source payment broker that facilitates payment requests to reside in the Operating System. The shared account ledger was intended to contain anonymized account balances that would be used to verify funds availability and to make payments. Changes made to individual accounts in COTA's central fare management system, as well as mobility provider systems, would be synchronized with the shared account ledger as part of an automated process. As a result of this change in architecture (i.e., not including the shared account ledger), the project relied on Bytemark's proprietary payment broker service to facilitate payment requests, meaning that future implementations of CPS by other agencies (were the CPS to have been successfully deployed) would also be reliant on Bytemark for this service.

8.3.1.7. PARATRANSIT SERVICE INTEGRATION

Integration with COTA's paratransit service provider, First Transit, could not be addressed during the demonstration period. No digital booking was available at the time, nor is it available today. Paratransit rides are only available by phone using the COTA reservation system. Integration did not occur due to the lack of an API for the Pivot app to ingest into its trip optimization engine. Integration with paratransit services may occur by the end of 2021.

8.3.1.8. DEEP LINKING

In response to the removal of CPS, the City continued conversations with mobility providers to present options for integration given the challenges identified above. Options for participation in Pivot were offered for assessment by mobility providers, as summarized below:

- Acceptance of CPS as a form of payment (like Apple Pay or Google Pay)
  - All mobility providers indicated that this could not be completed within the project demonstration period
- Payment integration with Pivot through established methods of deep linking
  - All mobility providers indicated this is the preferred option from a schedule and level of effort perspective

The City reviewed and discussed the options, and determined to move forward with deep linking. Mobility providers indicated that while deep linking could be completed, it would take additional time and effort to complete this type of integration. Due to the pandemic, the timing had to be fluid, and the mobility providers could not commit to completing this by October 1, 2020 (original go-live target). The Pivot app with deep linking capabilities was officially launched on December 9, 2020.

8.3.2. Schedule and Cost

As described in the previous subsection, the MMTPA/CPS project continually realized risks identified in the Risk Register related to the project's scope. These changes similarly affected the project's cost and schedule, since many of the changes required contract and agreement updates between the City and the project's vendors and partners. These impacts are summarized below:

8.3.2.1. SCHEDULE

- The original program schedule had the Pivot app development beginning in December 2018 and being publicly available (without the CPS), in August 2019. The Pivot app development schedule was aggressive; however, the team was able to begin work on schedule, meet intermediate release deadlines, and the app (Release 3) was made publicly available on August 29, 2019. While MMTPA remained on schedule initially, CPS development encountered delays that impacted the overall project:
  - The original program schedule had the CPS development beginning in April 2019 and COTA being integrated into both CPS and the Pivot app in January 2020. Additional mobility providers were to be added through May 2020. The development of CPS began as scheduled; however, previously discussed items delayed the schedule and ultimately led to the removal of CPS.
- A change in scope to include Merchant of Record services in Bytemark's contract required additional time to negotiate and finalize between the City and Bytemark.

- Sub-merchant agreement negotiations between Bytemark and mobility providers began in February 2020 until the onset of the pandemic; by which time no agreements had been fully executed, with providers citing pandemic impacts as one of the reasons. The need for these agreements was a driver for the launch date of CPS.
- The City was negotiating ownership terms that could be transferred to COTA's long term agreement of the Pivot app at the time of the pandemic. The onset of the pandemic paused and ultimately ended these negotiations and an agreement was not signed. COTA notified the City in July 2020 that the agreement could not be pursued due to its ongoing work on its existing fare collection system and the pandemic's impacts to revenue and resources.
- Development on the project paused from May to August while negotiations with mobility providers and COTA were ongoing. Once COTA withdrew as the owner and participant in CPS in July 2020, the City then worked with USDOT in July and August to outline a new path forward for the project, focusing on implementing the deep linking approach. This approach required additional work from the Pivot vendor, Etch, to enable deep linking. USDOT concurred with this approach in early September, and the development was done through November 2020 with a public release in early December.
- Acceptance testing of the revised Pivot app began in late October 2020. The testing identified some corrections and enhancements that were prioritized for public launch. Therefore, to accommodate the development time needed to implement these changes, the launch was delayed from early November to December 9, 2020, which also accommodated the sensitivities of launching during the 2020 Presidential election and anticipated protests in the city during this time.

8.3.2.2. COSTS

- The vendor estimates for the MMTPA and CPS projects were $1.38 million and $1.78 million, respectively. Both vendor's proposals were below the City's estimates for these projects. For the MMTPA project, the City received 18 proposals, with an average cost of $3 million. For the CPS project, the City received five proposals, with an average cost of $2.4 million.
- The removal of CPS resulted in an overall budget reduction for the program of $1,267,047.

8.3.3. Changes to Stakeholders and Partners

8.3.3.1. OWNERSHIP

Conversations with COTA around the transfer of ownership of Pivot were ongoing at the start of 2020 and ended mid-year. The team included COTA in negotiations with Bytemark so that the terms were amenable to COTA, and could easily be incorporated into an agreement between COTA and Bytemark. Throughout the first quarter of 2020 and into the early part of the second quarter when the impacts from COVID-19 occurred, it was assumed that COTA would continue its role as project champion and future owner of the Pivot system; however, by the summer of 2020, COTA made the decision that it could not assume ownership due to challenges caused by the pandemic, losses in ridership/revenue, and the decision to focus on updates to both the hardware and software components of its fare management program.

8.3.3.2. MERCHANT OF RECORD

Bytemark assumed the role of Merchant of Record for the Common Payment System. This included assuming all responsibility for the collection, reconciliation, settlement and disbursement of funds received through the CPS; maintaining Payment Industry Data Security Standard (PCI-DSS compliance); collecting payments and account loads by customers; reconciling and distributing payments to mobility service providers; processing all other financial needs, as necessary, to operate the CPS system which includes processing refunds; and assuming liability for all customer and mobility service provider funds while in CPS. Bytemark would also have been responsible for preparation and execution of sub-merchant agreements between itself and mobility service providers, with review and input from the City.

8.3.4. Challenges

This section summarizes the root causes for the changes discussed in the previous section, specifically the removal of CPS due to the previously discussed scope changes and agreement challenges, all exacerbated by COVID-19.

- Ownership of Pivot – as discussed earlier in the chapter, the challenges with finalizing a specific agreement to own and operate Pivot, COTA's fare management system, and ability to enable widespread adoption/use of contactless and equitable payment were exacerbated by COVID-19 and ultimately resulted in COTA backing out as the long-term business owner for both the Pivot app and CPS.
- Delayed Sub-Merchant Agreements – the process to define and finalize sub-merchant agreements began in mid-2019, with the City and Bytemark (CPS vendor) first working through the finalization of Merchant of Record responsibilities. Once it was decided that Bytemark would serve in this role, Bytemark began negotiations with mobility service providers in early 2020, a process that quickly stalled due to the many legal, financial, and liability challenges that emerged during this process. These challenges were also exacerbated by the impacts of COVID-19 on mobility providers (loss of resources, change in personnel, and loss of revenue), ultimately causing negotiations to be halted completely while the risks and questions regarding COTA as a future owner and participant were resolved. The revised development approach to deep linking with the mobility providers did not require a Merchant of Record since the integration with Pivot enabled payment functionality to remain with the mobility providers.

The following concerns were voiced by mobility providers during negotiations to participate in both the MMTPA and CPS projects:

- Submerchant agreement and associated fees[87]
- Customer ownership "who owns the customer"
- Loss of Mobility Provider branding/experience by using CPS
- Data ownership (i.e., reluctance to allow cost comparison with potential competitor services)
- Accountability (i.e., how to ensure overall privacy of financial data)
- Audits and payment/revenue protections

Other issues brought by mobility providers, unrelated to agreements, included:

- No "guest checkout"; provider accounts needed to be a requirement
- User experience (seamless registration and payment flows needed to be documented)

[87] For each CPS payment transaction, mobility providers were asked to agree to a percentage on volume as payment processing and transaction fees. Per agreement with the City, Bytemark required a per wallet load transaction fee; mobility providers would be responsible for a Per Ride Transaction Fee of 2% to help cover the fee, and the City would be responsible for the remainder. All fees would be deducted immediately upon services requested by end user; Bytemark would retain the fees and settle with the mobility providers as provided in the terms of the submerchant agreement.

- Details on incentives offered to try mobility provider services
- COTA ownership (transit viewed by some as indirect competition)
- Cost comparison with direct competitors (e.g. Lyft and Uber)

8.4. CONCLUSIONS, LESSONS LEARNED AND RECOMMENDATIONS

The service gaps that the MMTPA/CPS project intended to address were as follows:

- Disparate mobile apps require travelers to download and install multiple apps and register multiple payment media to plan and pay for multimodal trips
- Lack of a comprehensive platform to plan, book, and pay for multimodal transportation
- City agencies do not control the trip data, and face obstacles when requesting trip data from mobility providers
- Trips not optimized for ridesharing
- Unbanked users (e.g., individuals without credit or debit cards) must rely on cash for transportation options
- Lack of incentives for mobility providers to be part of a Mobility as a Service (MaaS) solution
- Lack of incentives for travelers to engage in multimodal trips

The MMTPA/CPS project addressed or partially addressed most of the gaps in service identified in Columbus as established in the project ConOps, aside from those tied directly to the CPS. The gaps in service that were met included: lack of a comprehensive platform to plan-book-pay for multimodal trips, lack of control over mobility data (and obstacles faced when trying to request trip data from mobility providers), as well as trips not being optimized for ride-sharing. While integration with the CPS was not achievable, the Pivot app was able to facilitate trip payments through deep linking with third-party mobility apps. However, the original vision for a Smart Columbus wallet, which travelers could use to pay for multimodal trips through a single account-based system, was not achieved.

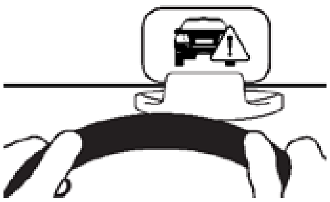
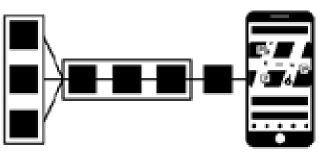
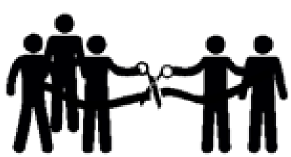
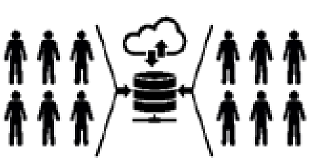
In working with mobility providers to incentivize them to join the Pivot app and CPS, many common issues arose. These included ownership of the customer, how to ensure privacy of financial data, protection of brand, and competition with other providers (including perceived competition with transit among other mobility providers). Throughout negotiations with mobility providers, the Smart Columbus team aimed to incentivize providers through reduced transaction fees, brand loyalty through account linking (not taking customers away from their own apps), expanded reach into underserved markets, Smart Mobility Hub co-promotion, and promotional support through integration with the local transit authority and ridership. These incentives continue to be important ways to incentivize providers for other agencies.

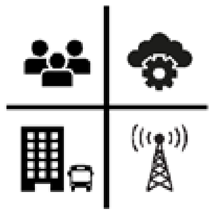
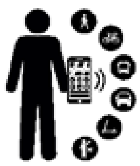
The needs of the unbanked in Columbus have not been fully served through the Pivot app implementation mostly due to removal of the CPS project. Without a Smart Columbus wallet there is no mechanism in the Pivot app to support unbanked travelers, and no method for the unbanked to fund a transportation wallet using cash. As part of COTA's fare collection system upgrade, a goal is to develop a wallet solution to include for bus payments.

8.4.1. Smart City Vision

The MMTPA project addressed city challenges and met several of the original expectations defined in Columbus' smart city vision. The project also addressed transportation challenges by deploying applications and strategies which satisfy the USDOT smart city vision elements shown in **Table 8-8**.

Table 37: Multimodal Trip Planning Application Project Relationship to USDOT Vision Elements

VISION ELEMENT #3 Intelligent, Sensor-based Infrastructure 	The Pivot app running on IKs at Smart Mobility Hubs brings the city's transportation options together at a single location where travelers can find mobility options quickly and efficiently. Trip plans can be created at the kiosks and sent to traveler's smartphones for immediate trip execution. Pivot also indicates the number of available scooters at each Smart Mobility Hub location.
VISION ELEMENT #4 User-focused Mobility Services and Choices 	Pivot provides a comprehensive planning tool that can help travelers get to their destination using multiple modes of transportation. This helps improve mobility, reduces congestion, and increases access to jobs and services for travelers in the Columbus region. The ability to plan, book, and pay for multimodal trips is facilitated through a single platform with deep links to third-party apps to handle individual trip payments.
VISION ELEMENT #5 Urban Analytics 	Trip data from Pivot (stored on the Pivot Hyperledger Blockchain) are transmitted to the Smart Columbus Operating System through a secure API, allowing access to travel patterns and traveler behavior data that was previously inaccessible to the City through mobility providers. Data are aggregated and de-identified to protect the identities of individual travelers and mobility providers. The Pivot routing engine uses machine learning to make recommendations based on traveler behavior and preferences, and to provide trip optimization based on data from INRIX and transit on current and historical conditions.
VISION ELEMENT #7 Strategic Business Models and Partnering 	Pivot brings together public and private mobility providers into one platform. This was accomplished through permitting requirements, contractual agreements, and partnerships.
VISION ELEMENT #9 Connected, Involved Citizens 	The design of Pivot relied on inputs from numerous community groups (as well as mobility providers) who participated in the app's concept development stages through testing and launch. Users are able to leverage broad access to mobility information and analytics as a result of Pivot, through data that are continuously ingested into the Operating System.

VISION ELEMENT #10 Architecture and Standards 	The program team developed the project's Intelligent Transportation Systems (ITS) architecture using ARC-IT/SET-IT, for the repeatable development and deployment of Pivot app. Pivot is designed on a foundation of open and proven technologies with no dependencies on subscription services, proprietary code, or commercially licensed data. Elements of the Pivot solution that do not violate mobility provider agreements are customizable and available as open-source software which can be redistributed by other cities/agencies.
VISION ELEMENT #11 Low Cost, Efficient, Secure, and Resilient Information and Communications Technology 	The Pivot app was developed to be a low-cost solution using integrated, open-source technologies, including OpenTripPlanner, OpenStreetMap, Pelias GeoCoder, and Blockchain Hyperledger[88]. All data stored by Pivot are encrypted in transit (HTTPS) and at rest (Amazon encrypted Elastic Block Store / Relational Database Service). User data are stored in a cryptographic ledger which helps to ensure integrity of data. Individual data records cannot be tampered with without changing the entire cryptographic hash chain. All data, including logs, are stored either on Elastic Block Store or in Amazon's Relational Database Service.

Source: City of Columbus

8.4.2. Conclusions

8.4.2.1. CPS

True MaaS cannot be achieved without the seamless ability to pay for any combination of transportation services. Solidifying the enterprise architecture for the payment coordination is key to identifying all potential policies and agreements that are necessary for implementation. For example, mobility providers had several legal, business, data, and customer ownership requirements to gain concurrence on their participation and commitment. Working through details early and as often as possible can help in keeping the project moving.

This process can and will take time but may be mitigated by incremental development and integration (as described in **Section 8.4.3**), a strong project champion/owner, and incentivizing mobility provider participation (whether by subsidizing costs/trips through the MaaS platform or outlining the business case for their participation by identifying benefits).

When developing a common payment system, deep linking with mobility providers is a viable stop-gap solution to allow time for payment terms and conditions and agreements to be put in place. It is imperative to convince service providers of the benefits of joining a system in cases where a city does not have the regulatory control to enforce it.

Because of the complexities of terms and conditions with each provider, the technical challenges of implementing an account-based payment system may seem like the easy challenges to address. Successful development of a CPS requires work, commitment, and timing, as well as the vested interest of all parties involved.

88 *User data is stored in a cryptographic ledger which helps to ensure integrity of data. Individual data records cannot be tampered with without changing the entire cryptographic hash chain.*

8.4.2.2. MMTPA

A MaaS platform is achievable – the Pivot app aggregates the services of multiple mobility providers to facilitate multimodal trip planning and trip execution through a single interface with links to third-party apps for payment. To achieve MaaS, transit agencies should continue to serve in a key role. Cities often have regulatory/permitting mechanisms for providers, but public transit can build relationships to encourage connection to transit and building a MaaS system. All entities need to work together to be successful.

Moving forward, the City has allocated funds for continued investment in the application through January 2022. Services in 2021 include hosting and maintenance on Amazon Web Services (AWS) consisting of the Hyperledger blockchain and Kubernetes. Basic features and functionalities will be enhanced, including saving search history, auto populating search with most common trip locations, trip suggestions based on previous selections, a map view of trip options, and user interface and experience enhancements. The app will build upon the existing metrics to include gamification and rewards. Trip history will be used to suggest alternate modes based on traveler activity as well as using gamification to reward users with badges for using cost effective and environmentally friendly modes of transportation. Pivot will integrate with COTA's new fare product and incorporate booking with COTA Mainstream and COTA Plus services. Also, additional mobility providers will be added, as needed. The product roadmap will continue to evolve and grow as the transportation needs of the region change.

8.4.2.3. IMPACT TO RESIDENTS

The MMTPA project demonstrated how residents' lives can be bettered through more convenient access to mobility options. Lengthy and uncertain commutes, multiple bus transfers and long waits can be addressed through multimodal trip planning and integration with third-party apps for payment purposes. Challenges that residents face, such as first mile/last mile service and convenient travel options to and from job sites can be improved through more convenient options for finding quickest route, or least costly, or even the greenest route alternative. Through human-centered development, the MMTPA project sought to focus on individual user needs and personal preferences, which has proven to be vital to successful user adoption of the Pivot app and future success of the program in Columbus.

Essential Worker Uses Pivot for All Transportation Needs

Morgan is a mom of 4 who works in the hospitality industry in the Short North. She owns a vehicle but chooses to take the bus to work because it's easier than finding and paying for parking. **"I used to use Transit but with the real-time bus information, route information, and voice navigation in Pivot, I'm a convert. I even share it with my fellow bus riders so they don't have to guess which bus to take or what stop to get off at."** Pivot also helps with the transportation needs of her whole family. **"One day my daughter got out of practice early. I wasn't able to pick her up but through Pivot I was able to book her a cab ride home."**

Morgan, Essential Worker, Linden

8.4.3. Lessons Learned

This section provides lessons learned in deploying a fully integrated multimodal trip planning application and payment system and meeting the objectives set forth in the USDOT Cooperative Agreement identified for the Smart City Challenge. Many of these lessons learned will apply to other agencies considering implementation of a similar solution.

8.4.3.1. CPS

- **Agreements –** Although the City identified the need for these agreements soon after the CPS vendor was on board, the complete process and structure of the agreements took months to develop. Once all agreements were identified, time was required to negotiate each agreement in the enterprise architecture, a process that took longer than anticipated. Many agreements (specifically the sub-merchant agreements with mobility providers) ultimately stalled completely as COVID-19 impacted provider's ability to commit to an emerging project with uncertain outcomes.
- **Ownership –** Although the team recognized the importance of a project champion early on and identified COTA as that champion, ultimately COTA was unable to take ownership. It was not the sole reason for CPS being discontinued, but it was a major factor. The City and COTA worked together from the beginning to define the project and faced challenges along the way such as agreeing on the concept (shared wallet vs. common account) to issues and delays in integration with COTA's fare management vendor, to ultimately being unable to finalize a detailed agreement outlining the terms of ownership (and exacerbation of all these issues from COVID-19).
- **Timing –** COTA's ongoing redesign of its fare collection system was a major constraint on the project that was never adequately resolved. Despite the proprietary nature of the system, the development team was able to successfully complete farebox integration via QR codes through direct contract with its vendor (SPX/Genfare); however, integration would have been easier after the system upgrade was complete. COTA is now seeking to replace most of its existing fare collection equipment and systems with a new account-based, multimodal fare collection system. This time it is seeking to adopt open architecture that is scalable to support growth, and capable of accepting a variety of payments. The timing of this change in direction for COTA is unfortunate in that it would have been an ideal starting point for Smart Columbus to develop the MMTPA/CPS project with COTA in full ownership of the system and with open architecture and standards being a model deployment for other cities.
- **Merchant of Record and Fee Negotiations –** One of the impacts in the change of ownership was identifying the party who would serve as Merchant of Record for the CPS. In the original design of the system this role would be filled by COTA through its existing payment services partner. The City did examine taking on this role but was unable to do so and therefore engaged with Bytemark. This led to months of legal negotiations between the City and Bytemark to arrive at the terms of the Merchant of Record. The resulting fees were higher than desired (and unfavorable to the City) because Bytemark needed to cover its own financial risks. The City was willing to pay for a large portion of the fees so mobility providers would have lower transactional costs and would be incentivized to join CPS. The lesson learned from this arrangement is to have prioritized this activity earlier because of the unknown legal and financial challenges and risks that arise when creating the first of its kind multimodal transportation and payment system. The legal and financial risks introduced to all parties require a seasoned team of legal and financial experts to assist in negotiations.
- **Mobility Provider Vision –** It took longer than anticipated to put together the business case for mobility provider participation in CPS in part because the CPS solution was under development while the vision and ownership of the system was in flux. This made it difficult to communicate the system design effectively until much later in the project. The lesson learned is to have treated mobility providers as end users of the system earlier and to engage them more actively on their own vision.

8.4.3.2. MMTPA

8.4.3.2.1 Development

Agile development and incremental delivery of the Pivot app was the right approach to ensuring continuous feedback and refinement of key features. By focusing on smaller iterations, the development team was able to adapt to the many changes on the project and still deliver a valuable product and a strong foundation for future growth. In retrospect, it may have benefited the overall project to start with deep linking for payment purposes while developing the common payment system, if only to get mobility providers engaged earlier and agreements in place sooner. Also, less restrictive requirements for integration with COTA's proprietary fare management system, and the ability to install custom hardware, may have encouraged more interest from the private sector in creative ways to deliver the CPS. In retrospect, the CPS project may have benefited from pivoting to agile development following the ConOps instead of full system requirements, which constrained the solution and limited interest from private industry. Had both MMTPA and CPS followed the same development trajectory from the start, rather than dovetail together once the Pivot app framework was already developed, the solution as a whole could have been presented to mobility providers earlier as a complete working model to achieve acceptance and buy-in.

8.4.4. Recommendations

8.4.4.1. DEVELOPMENT

- Include focus groups early in the project to help guide and shape the user experience and user interface (UX/UI). These focus groups should reflect potential users of the system, such as transit users, college students, downtown residents and urban residents, community organizations, suburban commuters, and other stakeholders/partners.
- Consider groups that already use transit, such as transit advocacy groups.
- A similar group of users can also support a beta launch of the system, enabling continuous feedback, development, and improvement of the system’s functionality.
- Incentives for these testers will ensure prompt and thorough feedback, further helping the development team to identify and prioritize enhancements.

8.4.4.2. BUG-TRACKING

- Implement proven tools to help automate the reporting of bugs and enhancements, particularly ones that collect system data and screenshots from beta testers for developers to easily see where a bug may exist and rectify it. Do not rely on email and spreadsheets only for communicating status.
- For user acceptance testing, ensure that the development team is not responding to issues on-the-fly unless those issues are truly preventing testing from occurring. Fixing issues on-the-fly can and will lead to other issues downstream causing the test team to become stuck in regression testing the same issues over and over.

8.4.4.3. AGREEMENTS

- Seek to obtain signed MOUs with partners early in the engineering process once user needs are established and before finalizing the ConOps. Having MOUs in place will make transitioning to real agreements, especially where financial transactions are concerned, smoother as there will be common understanding and shared goals.

- Choose partners carefully and make sure they have the same vision and goals and understanding of the project. Mobility providers will have competing interests with their own apps and other providers and may even view transit as a competing interest.

8.4.4.4. MOBILITY PROVIDERS

- Communicating the benefits of a common payment system to mobility providers is a difficult sales pitch. A white paper and flow diagrams will help in explaining the benefits, especially concerning the flow of money and payment processing.
- The original scope had mobility providers conforming to a strict API; Etch changed this by modifying Pivot's architecture to accept mobility providers' APIs. This required less work for mobility providers and made them more willing to participate.
- Mobility providers are concerned about "owning the customer" and protecting their own brand. They are also concerned with taking users away from their own apps. Deep linking is universally preferable to mobility providers because it drives users to their app and maintains contact with the customer.
- Start negotiations with mobility providers early; amending existing agreements for CPS integration was a difficult process.
- Consider bringing mobility providers on in stages starting with the most amenable (or local providers) to show successful integration before attempting to bring on additional providers (the national providers).
- City permits and licensing with mobility providers may require modification to ensure participation in the project.
- Be ready to accommodate new providers and modes and have an onboarding plan.

Pivot Helps Local Mobility Providers Access New Users

"As transportation habits have changed, local mobility providers like myself have had to find new ways to engage and serve the mobility needs of our community. Yellow Cab of Columbus is proud to partner with Pivot to help us connect with more people as travel increases"

Morgan Kauffman, CEO of Yellow Cab of Columbus

8.4.4.5. COMMUNICATIONS

- There are bound to be many changes as the app develops. Make sure the communications team has a regular seat at the table from the beginning and leverage the skillset to share updates with key stakeholders throughout the process.

- Ensure there is alignment between the communications and technical teams about what criteria the app needs to meet before public promotion can start.
- Work closely with the technical team for the inclusion of app analytics as part of the development plan to ensure event tags are set up that can measure use of the app, informing post-launch promotion.
- Leverage key stakeholders' communication channels to assist in getting the word out upon launch. Third-party validation will assist in building trust with the user.
- Solicit testimonials from users to help promote the app.
- Leverage entertainment events or milestones like starting a new job or college as entry points to reach potential users.
- Providing demonstrations of the app assists in adoption. Find ways to conduct demonstrations in community meetings or on-location at festivals, bus stops, or popular shared-used device pick up/drop off points.

8.4.4.6. COMMON PAYMENT SYSTEM

- Having a private company assume the Merchant of Record role in place of a public agency or transit agency may result in higher fees per transaction due to the assumed risk.
- Make sure the team includes fiscal experts when negotiating fees.

ES-5.6.1. REQUESTS FOR PROPOSALS AND CONTRACTING

If attempting to develop a common payment system, seek proposals including a traditional bank as a partner to help facilitate financial hurdles. Consider making an established partnership with a financial institution a selection criterion in the RFP.

- For development projects that pivot from V-Model systems engineering to Agile, be clear on technical requirements that are absolutely needed in the RFP.
- Have contingency dollars to accommodate changes, as new providers may emerge and how they integrate to the system may need to evolve.
- Robust documentation is not the focus of Agile development; take advantage of short development cycles to frequently review product backlog and keep a change management log with traceability to system requirements. A Hybrid of traditional V-Model systems engineering and Agile development methodology is preferred for app development over a pure V-Model approach; however, extra effort is required to track, approve, and document changes.
- Include funding to make enhancements/improvements to the app after it is released to the public. The City allocated 10% of the MMTPA/CPS project development cost for improvements after public release, which was adequate.
- Consider including in the RFP which modes and/or providers are required, and leverage existing relationships that solution providers can offer.
- It would also be beneficial to require the developer to define an onboarding plan for new modes as a contract deliverable; this would streamline and simplify the process when new providers enter the market.

- Consider vendors with established relationships with mobility providers in the region and a proven and flexible framework upon which to develop new features and functionality. With an existing framework, all of the custom requirements may not be achieved, but there will be gains in other areas such as platform stability, polished functionality, and a potentially large existing user base. Also, project risk can be minimized and needed agreements can be accelerated by leveraging existing relationships with mobility providers.
- Require that mobility providers supply a common standard data feed such as General Transit Feed Specification (GTFS) and General Bikeshare Feed Specification (GBFS).

8.5. SUMMARY

Developing a MaaS system integrated with public and private mobility providers and a common payment platform presents many technical, financial, and legal challenges. Even with these hurdles throughout the project, the Pivot app was able to successfully launch and address many needs identified by the public, as well as achieving the USDOT's vision elements. As Pivot continues, the app will be an integral part of the City's transportation system, collecting data and serving as a tool to provide transportation options for the public.

Chapter 9. Mobility Assistance for People with Cognitive Disabilities

9.1. PROJECT OVERVIEW

A cognitive disability can make it difficult for someone to get around independently[89]. Driving a car is typically not a viable option, and to use public transit, individuals must either qualify for paratransit services or be able to safely use fixed-route bus services without assistance. Providing paratransit services is expensive for transit providers, and rides often require 48 hours' advance notice.

The goal of the Mobility Assistance for People with Cognitive Disabilities (MAPCD) project was to enable more independent travel via fixed-route bus service for individuals with cognitive disabilities, many of whom rely on caregivers for transportation using privately owned vehicles. To do this, the MAPCD project provided a solution that offered accurate, customized turn-by-turn navigation with other support features ensuring that users with cognitive disabilities can safely and confidently complete a trip using the fixed-route bus service. The project team decided upon a "caregiver response model" to assist users, in which a relative or caregiver of the traveler monitors the trip and intervenes as necessary. The alternative to this model involved external support from an outside agency or call center to monitor trips and intervene as necessary; however, the study team evaluated call center support from Central Ohio Transit Agency (COTA) early on and found such support not feasible due to costs and limited staff resources. This project sought to provide an example of empowering all residents to live their best lives through the following activities:

- Allowing travelers with cognitive disabilities to transition from using paratransit services to independent travel using fixed-route bus service
- Provide caregivers with an interface to create individual routes for travelers and be able to view traveler's progress on a map
- Collect anonymized data on app usage and travel behavior in the Smart Columbus Operating System (SCOS) for performance measures and analytics

Based on the collective experience of the staff and faculty at The Ohio State University (OSU), and The Ohio State University Wexner Medical Center (OSUWMC), and USDOT's Accessible Transportation Technologies Research Initiative (ATTRI)[90], the project team sought a solution that provided an accessible smartphone app with multimedia prompts to individuals with cognitive disabilities for navigating public transit systems. The final solution selected by the project team was AbleLink Smart Living Technologies' WayFinder app, which was developed through funding from the U.S. Department of Education (USDOE) and the National Institutes of Health (NIH). WayFinder has continued to be enhanced as part of an ATTRI contract with USDOT.

[89] *Cognitive disability entails a substantial limitation in one's capacity to think, including conceptualizing, planning, and sequencing thoughts and actions, remembering, interpreting subtle social cues, and understanding numbers and symbols. Cognitive disabilities include intellectual disabilities and can also stem from brain injury, Alzheimer's Disease and other dementias, severe and persistent mental illness, and, in some cases, stroke.*

[90] *https://www.its.dot.gov/research_archives/attri/index.htm*

Table 9-1 summarizes the user needs for the solution the MAPCD project sought.

Table 38: User Needs

Evaluation Criteria	User Class	Priority
Phone-based app (Android and iOS)	Traveler	Essential
Knowledge of real-time transit info COTA General Transit Feed Specification (GTFS)	Traveler	Essential
Voice and turn-by-turn directions	Traveler	Essential
Ability for the traveler to speak to the caregiver (safety)	Traveler	Essential
Ability to send alerts to the caregiver (passive monitoring)	Caregiver	Essential
Ability to track an individual (active monitoring)	Caregiver	Essential
Caregiver experience[91]	Caregiver	Essential
WCAG 2.0AA Standard / 508 compliant	Traveler	Essential

Source: City of Columbus

WayFinder a highly detailed, turn-by-turn navigation app specially built for people with cognitive disabilities. WayFinder enables persons with cognitive disabilities to travel with greater independence and autonomy, and transition from paratransit services to fixed-route transit systems. Phone-based GPS tracking allows WayFinder to safely guide users with step-by-step visual and audio instructions. The app also allows their caregivers to develop instructions based on the unique needs of the travelers. This solution gets participants from Point A to Point B safely using the bus, making it easier to independently make novel trips like going to the grocery store or getting to work on time. AbleLink provided real-time data to the SCOS via an encrypted point-to-point virtual private network tunnel; AbleLink provided a RESTful interface to allow the data to be extracted in real time.

The MAPCD project was conducted in partnership with OSU, who played a critical role assessing the existing applications, conducting an evaluation of the technology, and completing a field study of wayfinding applications. The field study was completed as part of Pre-Vocational Integrated Education and Campus Experience (PIECE) program through a partnership between the Nisonger Center at OSU and Franklin County Board of Developmental Disabilities (FCBDD) Adult Services. The PIECE program provides individuals with intellectual and developmental disabilities with prevocational skills and community support, which includes utilizing multiple modes of transportation. The MAPCD project launched in 2017 with initial research and definition of the user needs. Following the completion of the trade study in 2018, the City contracted with AbleLink to complete application enhancements, and OSU began recruiting and training study participants. After testing was conducted in the first quarter of 2019, the study launched in April 2019 with travelers and caregivers using the solution and OSU regularly engaged with participants via interviews and surveys to gather findings and results.

[91] *The caregiver experience is a qualitative measure of the degree to which the application meets the primary needs of the caregiver, which are ease of use, ability to create routes, and ability to tailor the end-user experience to suit the needs of an individual user.*

9.2. DEPLOYMENT SUMMARY

9.2.1. Systems Engineering Approach

As introduced in **Section 9.1**, the MAPCD project concept was able to leverage the work of USDOT's ATTRI program, which provided several key research documents including institutional and policy assessments, innovation scans, and even user needs. This provided a head start when kicking off this project. Due to this research program, established solutions were available and understood, and their requirements, capabilities, and designs were well-established. Therefore, a tailored V-Model process (described in **Chapter 2**) was followed. While the project team still conducted their own assessment of user needs and evaluation of technology, certain documents were not required, including the Systems Requirement Specifications (SyRS) and System Design Document. For the MAPCD, the project advancement process included a Trade Study replacing the Concept of Operations, and an Interface Control Document (ICD) replacing a complete set of SyRS. The ICD provides the specific requirements to integrate the existing solution into the Smart Columbus Program and ensured the selected vendor can satisfy these requirements. To ensure satisfaction of user needs and interface requirements, a test plan and report were also completed to document solution verification and validation. Also, to assist future owners, an Operations and Maintenance (O&M) Plan was developed to document activities and costs associated with the solution.

For projects such as MAPCD that have existing solutions that do not require a complete design and build effort, a trade study was prepared to identify the most balanced technical solutions among a set of proposed viable solutions.[92] At the onset of the project, the team used the trade study to document and understand user needs with the input of many stakeholders including advocacy groups (COTA Mobility Advisory Board, COTA Accessible Transportation Advisory Committee), COTA paratransit staff, OSU faculty, and potential users and caregivers from the OSU PIECE program. The trade study included a functional assessment of existing applications while identifying strengths and opportunities for improvements with the existing applications. Criteria and weighting to evaluate the potential solutions were developed based on input from COTA and professionals at OSU who were directly responsible for evaluating and assisting people with cognitive disabilities who want to use public transportation services.

Based on the evaluation, AbleLink's WayFinder solution was picked as the preferred option for Columbus, provided that AbleLink successfully integrated functionality to actively track an individual on a route. Continued testing in partnership with OSU, as well as continued engagement with AbleLink was essential to further customize the product to meet the needs of the Smart Columbus Program. The ultimate solution that was implemented was called the WayFinder system, and four components comprise it: the WayFinder mobile app, the SMART Route Builder, the SMART Route Library, and the SMART Travel Manager (see **Figure 9-1**):

- **The WayFinder app –** A mobile app that operates on iOS and Android smartphones, using the global positioning system (GPS) on the device to provide geolocation-based prompts to system users. The WayFinder app sets up any number of routes based on a user's typical travel destinations.
- **The SMART Route Builder –** A web-based portal that simplifies the ability to create travel routes for various destinations. The SMART Route Builder gives caregivers the ability to create routes for WayFinder using a map-based interface and the ability to view real-time location tracking to show an individual's progress on a map.
- **The SMART Route Library –** A cloud-based library of routes to specific destinations that will provide easy access to cloud-based routes for specific geographic areas which can be downloaded and used as is or modified to meet the needs of travelers with cognitive disabilities.

[92] *Federal Aviation Administration (2006).*

- **AbleLink –** Cloud environment that hosts the SMART Route Library server application and SMART Route Builder website. The environment also hosts secure application programming interfaces to send de-identified travel information to the SCOS.

Figure 9-1: WayFinder Ecosystem

Source: City of Columbus

Given the priority on customization of the product, defined criteria for product acceptance, engagement with human subjects/participants, and the desire to share data between the solution and the SCOS, the following next steps were documented to ensure essential user needs were met, and to allow adequate testing prior to deployment.

- Draft and final ICD
- Institutional Review Board (IRB) approval and oversight
- Prepare and finalize draft contract with AbleLink
  - Product enhancement based on evaluation and feedback from OSU and OSU Nisonger Center PIECE program
- Test plan and results
  - Final product testing for acceptance and approval for launch
  - Draft and final test plan
  - Draft and final test results
- Participant Recruitment and Training
- Deployment and data collection
  - O&M Plan

Figure 9-2 summarizes the general timeframe for the project.

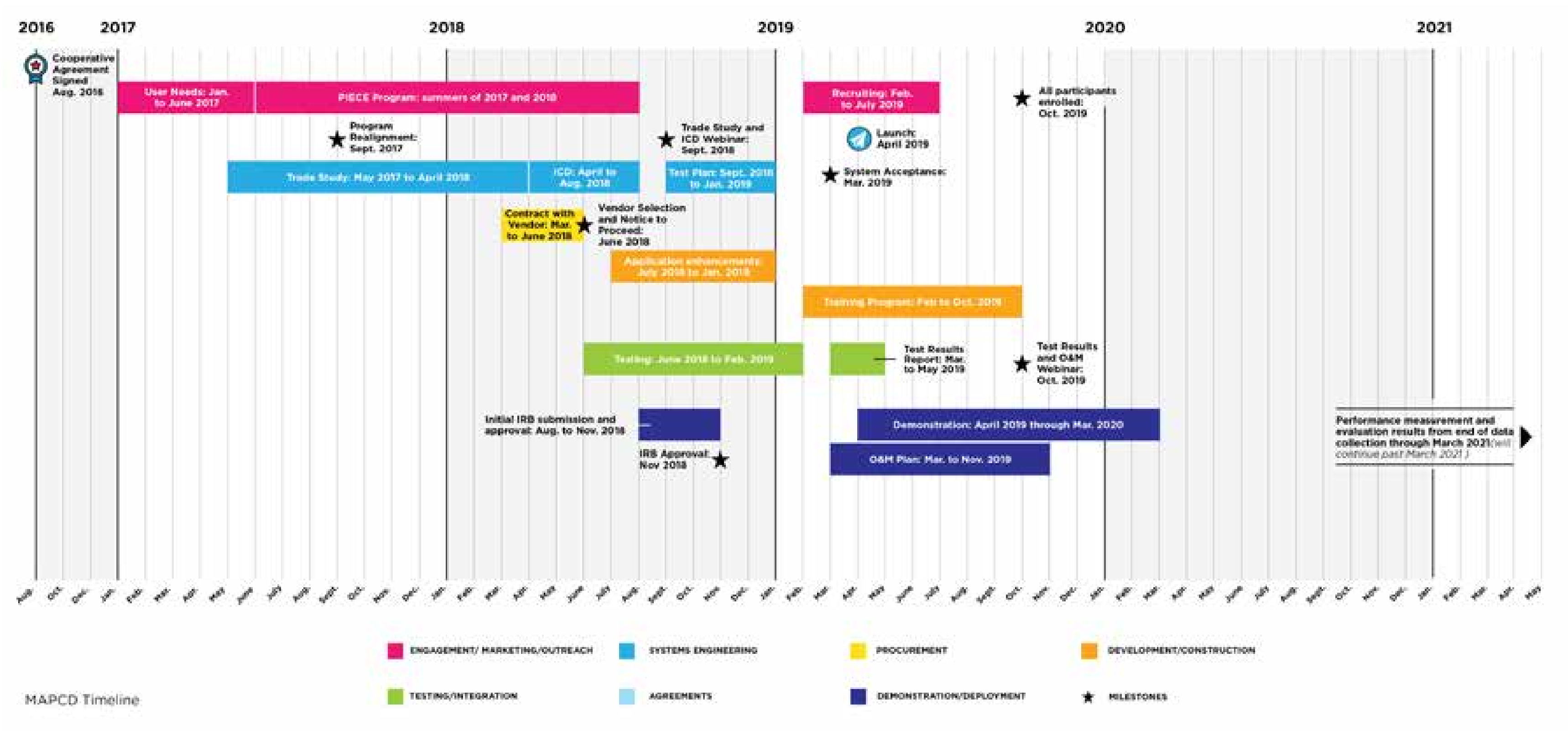


Figure 9-2: Project Timeline

Source: City of Columbus

9.2.2. Project Launch

The process to launch the MAPCD project took place over many months beginning in late 2018. Launch of this project required months of recruiting and training participants; the target was up to 30 travelers and their caregivers. OSU led the recruiting and training activities through their direct engagement with community mobility specialists (e.g., community specialists and occupational therapists) and community organizations, including ARC Industries, FCBDD, the OSUWMC Assistive Technology Center and the OSU Aphasia Initiative. This direct connection and collaborative relationship relied upon a network of communications and connections to potential participants; OSU then screened and evaluated each one for entry into the study.

The training process began with an OSU-led project called “The Personal Navigation for Individuals with Disabilities” (PNID) project, which began in the summer of 2018, and was the origin for the training approach and materials used for the MAPCD project. The final solution was tested and accepted by the project team in March 2019, at which point OSU organized a MAPCD community event to reconnect with stakeholders and provide information to the groups who could continue and expand recruiting efforts. As participants provided consent, they immediately began the training process. Rolling, iterative recruitment and training took place between February 2019 and October 2019.

The OSU-led PNID project training was modified during the recruiting period to reflect emerging needs from potential participants. There were multiple stages of the training program, beginning with an initial assessment of abilities, followed by travel training intake to determine which training should be completed. Participants then completed up to four training sessions: Safety training, public transportation training, general smartphone training, and WayFinder app use training. To accommodate the unique needs of the travelers, modifications were made to the training protocol to make the training as effective as possible for everyone. For example, one modification that was made for some participants was to bypass a particular training, such as safety training, if they demonstrated previous knowledge of and experience with the content of that training. To determine whether it was appropriate to omit a specific training, the traveler was asked to respond to the specific quiz questions before receipt of any related training. If they had sufficient pre-existing knowledge of the material, that content was omitted with the correctly answered quiz serving as a proof of understanding. The assessment of potential participants and training were typically completed in two to six weeks. Parallel to the travel training, the travel partners and caregivers received one-on-one training from a program instructor. The travel partner received training on route creation via the app and SMART Route Builder, route storage in the SMART Route Library, and traveler tracking via the SMART Travel Tracker. **Figure 9-3** shows images of a trainer and traveler interacting with the smartphone app.

Figure 9-3: Project Participant and Trainer

Source: City of Columbus

The MAPCD project launched the final application among the participants and their caregivers in April 2019. Smart Columbus hosted the event at the Experience Center to highlight the launch milestone, with one of the participants and trainers speaking about the impact of the application on his daily life (**Figure 9-4**). Overall, 31 travelers and 27 travel partners participated in the MAPCD project.

Figure 9-4: Project Launch Event at the Smart Columbus Experience Center

Source: City of Columbus

9.2.3. Demonstration

The demonstration phase of the MAPCD project consisted of the consented travelers and their caregivers planning and completing trips using the WayFinder solution from April 2019 to March 2020.

OSU managed all participant interactions, conducting surveys and focus groups during the demonstration period. Each participant was asked to respond to five surveys in total; four of these surveys evaluated the training materials, while one survey (offered bi-weekly) assessed satisfaction with the WayFinder solution throughout the demonstration period. In addition, the WayFinder system collected application usage data to assess number and type of trips. **Table 9-2** and **Table 9-3** summarize key findings.

Table 39. Summary of Participant Interactions

Metric	Number of Participants
Number of travelers who took a route with WayFinder	8
Number of travelers who completed biweekly surveys	8
Number of travelers who completed a focus group	2

Source: OSU

Table 40: Project Results

Demonstration Metric	Frequency
Total trips taken in implementation	82
Number of travelers who took a trip in implementation	8
Total number of trips with high user interaction[93]	10
Total number of trips with low user interaction[94]	47
Total number of other trips[95]	25

Source: OSU

Feedback from the travelers and traveler partners was obtained through quizzes, satisfaction surveys, questionnaires, interviews and focus groups. In addition, WayFinder app usage and trip characteristics were recorded for each trip via the WayFinder SMART Travel Manager. In addition to obtaining feedback from the travelers and travel partners, community mobility specialists provided feedback on the acceptability, usability, and feasibility of the WayFinder system and the training program.

Community mobility, which includes transportation, is an instrumental activity of daily living; therefore, numerous professionals are involved in the implementation process. The implementation process includes the identification of technology and training materials to support community mobility. A critical component of the project was the dissemination of information about the WayFinder System, the training materials, and the impact of the MAPCD program. As a measure of the acceptability, appropriateness and feasibility of the WayFinder System and MAPCD program, the team used the modified version of the acceptability of intervention measure (AIM), intervention appropriateness measure (IAM), and feasibility of intervention measure (FIM) [Weiner et al., 2017][96]. The modified AIM, IAM, and FIM was administered at the completion of numerous dissemination events (e.g., conference presentations and workshops). The results indicate that community mobility specialists consider the WayFinder system and the training program acceptable, usable and feasible for use in the community setting (see **Table 9-4**).

93 *High user interaction = Traveler responded to most of waypoints throughout the route (about 70% or more).*

94 *Low user interaction = Traveler responded to less than 70% of waypoints throughout the route.*

95 *Other trip = Off-route trip, no user interaction or unknown.*

96 *Weiner, B. J., Lewis, C. C., Stanick, C., Powell, B. J., Dorsey, C. N., Clary, A. S., Boynton, M. H., & Halko, H. (2017). Psychometric assessment of three newly developed implementation outcome measures. Implementation Science: IS, 12(1), 108.* https://doi.org/10.1186/s13012-017-0635-3

Table 41: Summary of Participant Feedback

General Feedback	Average Rating of Agreement (Out of 4 Possible)	
	Training Program	WayFinder System
Acceptability	3.5	3.5
Usability	3	3.5
Feasibility	3	2.9

Source: OSU

In addition, OSU also summarized results with respect to the following three case studies. Each case study highlights how different each traveler’s needs can be and how these differences might impact how travelers use the knowledge from the training program and the WayFinder system.

- **Case Study 1 –** This traveler is a middle-aged male with moderate visual impairments who traveled with a community specialist as his travel partner. This traveler reported being interested in traveling on the COTA fixed-route bus service and in learning to use a smartphone.

  Key Findings – Routes for this traveler were typically created by his community specialist for trips to shopping or recreational locations that the traveler would go to with his group of co-workers. Overall, the traveler felt more comfortable using public transportation after traveling with the WayFinder app even though he is still taking supervised bus trips.

- **Case Study 2 –** This traveler is a young adult male who did not have a travel partner, but he did have a proxy for communication with program trainers. This traveler reported having previous experience with the COTA fixed-route bus system and a smartphone, but he wanted to practice his skills with public transportation after an experience taking the wrong bus and getting lost, which left him with some anxiety about public transportation.

  Key Findings – To create routes for this traveler, audio cues and captions were added to tell the traveler that “This is not your stop” so that he was assured that he had not missed his stop. **After using WayFinder several times, the traveler felt comfortable traveling to work and no longer needed to use the app while riding the bus.**

- **Case Study 3 –** This traveler is a young adult female who has her parents as her travel partners. This traveler reported having no prior use with the COTA bus system, but she was interested in learning how to use public transportation. She also reported having previous experience with a smartphone.

  Key Findings –This traveler used WayFinder to take practice trips with her parent around Ohio State’s campus using the Campus Area Bus Service (CABS), which was appropriate for this traveler because there are fewer routes and a smaller geographic area than COTA fixed-route bus service. Since this traveler was new to using public transportation, custom images were added to the routes to assist her in making a correlation between her actual (or current) location and the travel instructions that were being conveyed to her via the prompt on the WayFinder app. The same route was repeated over the course of several trips to assist the traveler in gaining familiarity with the bus system and the WayFinder app.

9.2.4. Communications

Key communications activities for the MAPCD project focused on identifying user needs, recruiting participants, and disseminating project updates and findings.

OSU and COTA identified advocacy groups to help shape the project to meet user needs. Key stakeholders included COTA's Mobility Advisory Board, Accessible Transportation Advisory Committee and paratransit staff; OSU faculty; and potential users and caregivers through the OSU/FCBDD PIECE program. OSU faculty and students reviewed the user needs and performed a functional assessment of existing applications. The PIECE program was of great value; it enabled further identification of user needs, and field study and evaluation of the existing applications by potential users.

OSU and COTA led participant recruitment through their vast networks of disability advocacy groups and businesses. The project recruitment officially kicked off with a stakeholder event in April 2019. Initial recruitment focused on existing COTA paratransit users; however, potential participants did not want to enter the study because of their preference for the point-to-point service that paratransit provides. Businesses like ARC Industries, whose mission is to help people with disabilities gain skills and independence, were invaluable to helping identify participants.

The community and advocacy groups were very interested in project updates and findings. The Program Management Office (PMO) and OSU led dissemination of information through the following channels:

- **PMO**
  - **Smart Columbus Newsletters –** Weekly, highlighting key project accomplishments as necessary
  - **Webinars –** Two webinars to solicit comments on key deliverables:
    - Trade Study and ICD: September 2018, the Intelligent Transportation Society of America
    - Test Plan and Report and O&M Plan: October 2019, the Institute of Transportation Engineers
  - **Media stories**
    - "COTA with confidence: New program hopes to help cognitively disabled community take the bus in central Ohio," The Columbus Dispatch, July 22, 2019.[97]
    - "App helps people with cognitive disabilities ride public transit," NBC4, January 22, 2020.[98]
    - "Columbus, Ohio Is Piloting A Mobile App That Helps People With Cognitive Disabilities Use Public Transit," Forbes, December 15 2019.[99]
    - "New App Makes Mass Transit Accessible to People with Cognitive Disabilities," Streetblog, June 25, 2020.[100]
- **OSU**
  - International Seating Symposium, Pittsburgh, PA – March 2019 (international professional audience)
  - Community Stakeholder Event, Columbus, OH – March 2019 (local professional audience)

[97] *COTA with confidence: New program hopes to help cognitively disabled community take the bus in central Ohio - News - The Columbus Dispatch - Columbus, OH*

[98] *https://www.nbc4i.com/news/local-news/app-helps-people-with-cognitive-disabilities-ride-public-transit/*

[99] *https://www.forbes.com/sites/sarahkim/2019/12/15/smart-columbus-wayfinder-app/?sh=263deac3657b*

[100] *https://usa.streetsblog.org/2020/06/25/new-app-makes-mass-transit-accessible-to-people-with-cognitive-disabilities/*

- Rehabilitation Engineering and Assistive Technology Society of North America (RESNA), Toronto, ON – June 2019 (international professional audience)
- Ohio Occupational Therapy Association, Cuyahoga Falls, OH – November 2019 (regional professional audience)
- American Occupational Therapy Association, virtual – April 2020 (national professional audience)
- Assistive Technology Grand Rounds – OSUWMC, virtual – August 2020 (regional professional audience)
- RESNA, virtual – September 2020 (international professional audience)
- Ohio Center for Autism and Low Incidence Conference, virtual – November 2020 (national professional audience)

9.2.5. Project Costs

Table 9-5 and the figures below show the actual project costs, broken out by deployment and operations. It also illustrates the costs by vendor. Deployment covers the time from project beginning until launch, April 19, 2019. Operations runs from launch until the end of the demonstration period.

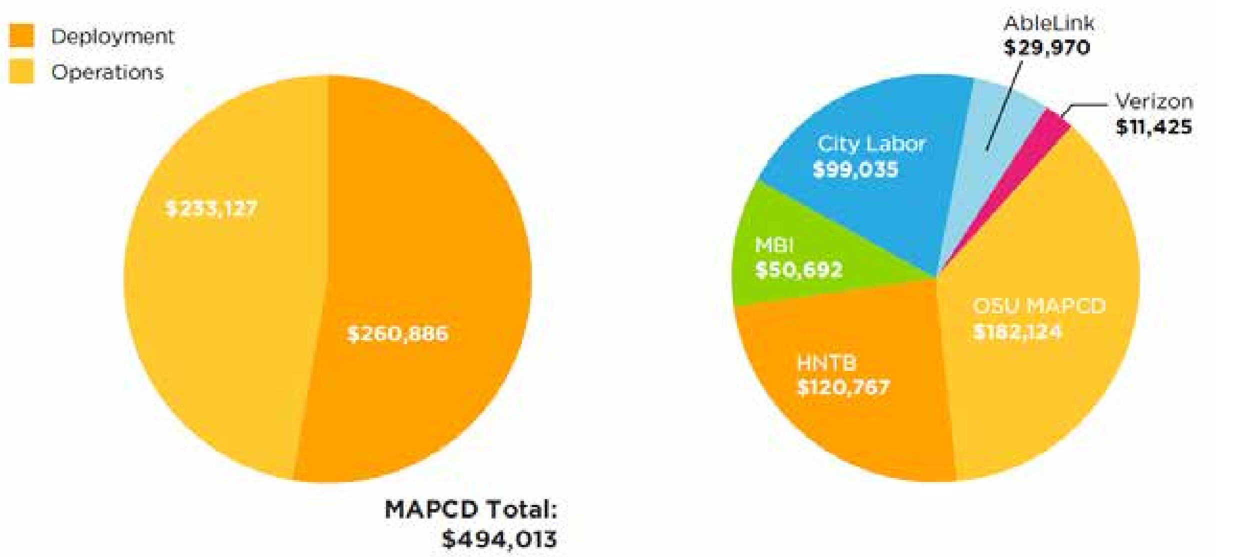


Table 42: Deployment and Operations Costs for the Mobility Assistance for People with Cognitive Disabilities Project

Vendor Actuals	Deployment	Operations	Total
AbleLink	$7,992.00	$21,978.00	$29,970.00
Verizon	$1,206.48	$10,218.75	$11,425.23
OSU	$66,861.21	$115,262.52	$182,123.73
HNTB	$90,828.20	$29,939.25	$120,767.45
MBI	$19,319.27	$31,372.51	$50,691.78
City labor	$74,678.98	$24,355.80	$99,034.78

Total	$260,886.14	$233,126.83	$494,012.97

Source: City of Columbus

9.2.5.1. KEY LEVERAGED PARTNERS

The WayFinder system was developed by AbleLink Smart Living Technologies, LLC, through research funding from USDOE, NIH, and a USDOT ATTRI grant. AbleLink contributed all labor hours for the MAPCD project, including development, enhancements, and project management. Some development work was already under way as part of the ATTRI grant awarded to AbleLink.

9.2.6. Project Stakeholders

The City led each project with vendor support critical to implementation. Vendors were primarily responsible for planning, documenting, testing and integrating, and delivery of system functionality. For MAPCD, **Table 9-6** summarizes these vendors and their roles.

Table 43: Project Vendor Responsibilities

Vendor	Role/Responsibility
AbleLink	Ÿ Lead developer of Wayfinder app Ÿ Responsible for developing the features and functionality to meet the needs of stakeholders Ÿ Maintained WayFinder
CELLCO Partnership (Verizon)	Cellular service
HNTB	Ÿ Systems engineering lead Ÿ Developed engineering documentation including: Trade study ICD Test plan and report O&M Plan Ÿ Coordinated with PMO, vendor and research team
Accenture	Responsible for implementing the interface to MAPCD to collect project data for performance measurement

Source: City of Columbus

While the project team worked throughout the Cooperative Agreement to develop, deliver, operate, and maintain the MAPCD project, stakeholders played a critical role in the process. **Table 9-7** summarizes the specific stakeholders that were engaged, as there were many diverse groups that came together to make the project successful. This table serves to highlight their contributions by categorizing them into the following three areas to indicate when their participation was used:

- **Systems Engineering –** These organizations/groups contributed to defining end-user needs, trade study or procurement documentation.
- **Development –** These organizations/groups contributed to the build out of the project. This includes installation, integration, testing, and recruitment/outreach planning.

- **Demonstration –** These organizations/groups that contributed to the operations and maintenance of a project from go-live to end of the demonstration.

Table 44: Project Stakeholders

Stakeholder	Systems Engineering	Development	Demonstration
Government			
City of Columbus Department of Public Service	X		
FCBDD	X		
USDOT	X		
Mobility Providers			
COTA	X		X
COTA Accessible Transportation Advisory Committee	X		
Educational			
OSU	X	X	X
Community/Advocacy Groups			
PIECE Program	X		
Columbus Advisory Committee on Disability Issues	X		
ARC Industries	X	X	X
Private Sector			
MassFactory	X		

Source: City of Columbus

9.3. PROJECT EVOLUTION

Overall, the execution of this project aligned closely with the original approach outlined at the onset of the program. The scope of changes to the project, summarized next, were relatively minor.

9.3.1. Technical Changes

The project trade study identified the essential and desirable features for the system of intere It was known that existing products would satisfy a majority of these user needs and that an end-to-end systems engineering effort was not necessary to design and build the solution. **Chapter 2** describes the different systems engineering approaches.

When evaluating existing products during the trade study process, it was noted that while the WayFinder product scored the highest, there were gaps in functionality that would require additional development, namely the ability to successfully integrate functionality to actively track an individual on a route and integrating data from the MAPCD solution to the SCOS. Therefore, continued testing in partnership with OSU was recommended prior to acceptance testing, with the understanding that should this testing reveal additional customization to the WayFinder solution, AbleLink would also implement these changes. The list of additional enhancements that were made are summarized below:

- Added the capability to modify the font size for displayed text associated with each waypoint.
- Added the capability to set a time delay in seconds for when a waypoint instruction would be repeated.
- Added the capability to de-identify trip data to obscure any personally identifying information when trip data was requested via the SCOS.
- The “off-route” detection algorithms were optimized to limit false positives as a result of feedback from test routes traveled prior to the start of the implementation period.
- The capability to use bus arrival time data from the Trip Updates GTFS feed was implemented to provide WayFinder users with bus arrival information within their WayFinder route.
- The capability to display COTA route alerts was added to the system to allow users to view real-time alerts while using WayFinder.

Figure 9-5: Project Training Session

Source: City of Columbus

Additionally, as noted in the previous subsection, due to the iterative recruiting and training process, modifications were made to the training approach and materials throughout the demonstration:

- If a participant demonstrated prior knowledge on the training content area (e.g., safety training), then they didn’t have to complete the training. The participant’s prior knowledge was assessed through quizzes.
- For the public transportation training (**Figure 9-5**), some participants did not complete the training at the COTA public transportation training facility and practiced public transportation skills on a fixed bus route or another form of public or private transit. In these instances, the travelers had prior experience using public transportation and their travel partner felt comfortable with the traveler’s knowledge, skills, and experience with public transportation.
- The travelers had the option to practice using the WayFinder app on a fixed bus route in real-time instead of attending the Public Transportation Training at the transportation facility (in this case, the COTA facility). This modification was due to constraints on personal schedules and business hours of the COTA facility.

- Smartphone training was tailored to each traveler due to the range of experience each participant had with the device. The training was omitted if the traveler already owned a personal smartphone and/or had significant experience using a smartphone. For those circumstances, the program trainer could download the WayFinder app to the traveler's device or the phone provided to them. These participants directly proceeded to the WayFinder app training since they were optimally familiar with their devices to engage in the study.
- Specific modifications were made throughout the travelers' training process due to the travelers' range of abilities, which was evident in the WayFinder app training. The modifications were made at the discretion of the research team after discussion on the appropriateness of the changes being made for the traveler. No specific modifications were made until consensus was reached among the research team. Program instructors were able to make minor modifications when a precedent had been established.

The final change to the project was that it was originally intended to continue through April 2020. With the onset of the COVID-19 pandemic, the project ended early due to stay-at-home orders that were in place in Ohio beginning in March 2020. Additionally, remaining interactions with participants (interviews and focus groups) had to take place virtually instead of in-person, which may have limited the number of responses that were ultimately received.

9.3.2. Changes to Stakeholders and Partners

One of the main areas in which the MAPCD project evolved was in the stakeholders who directly influenced the project scope, especially in participant recruitment and training and system operations. As initially laid out, the project roles were as follows:

- The PMO served as the product owner, with the responsibility for working with all stakeholders to ensure the project scope, schedule and budget were satisfied, in addition to leading administration of contracts with vendors and OSU to support the research, development and testing of the solution.
- OSU was the research lead, with the responsibility for contributing to the Cooperative Agreement deliverables (trade study, ICD, test plan and report, and O&M Plan) and leading the development of recruiting and training materials, testing, and demonstration oversight, especially coordination and collection of participant input.
  - OSU's existing PNID project, although separately funded by OSU, was a key point of collaboration for the MAPCD project given the common alignment around improving mobility for people with disabilities.
- The OSU Nisonger Center, a co-administrator of the PIECE program, was a key avenue for user feedback on challenges and solutions to independent travel via a fixed-route bus system. COTA provided paratransit expertise through its paratransit staff, Mobility Advisory Board and Accessible Transportation Advisory Committee. OSU Nisonger Center also contributed resources to execute the training of participants, making its facilities and transit training available. It was originally envisioned that COTA paratransit riders would be among the pool of participants for recruiting and that the MAPCD project would be coordinated with existing COTA initiatives such as their plans for providing paratransit on demand.
- FCBDD is a joint administrator of the PIECE program and supported the recruiting activities. Originally, it was envisioned that the FCBDD would contribute to the definition of user needs and evaluation of the initial WayFinder application.
- Project participants included both travelers (people with cognitive disabilities who were the end users of the WayFinder app) and their caregivers (a guardian, family member or community specialist who is responsible for creating and managing routes for the traveler)

The stakeholders who were involved remained consistent, yet their roles and contributions did evolve over time. In addition, as recruiting got underway, the initial slow response caused the project team to pursue additional avenues to achieve the desired target number of participants. Key changes with respect to stakeholder involvement primarily relate to the areas described next.

9.3.2.1. RECRUITING:

- Initially, it was envisioned that COTA would be a key resource in this area, as the goal was to move travelers from paratransit to fixed-route service. However, as recruiting began, the advocacy groups had much greater success but the travelers who were interested were those who had typically relied on caregivers for transportation via personal vehicles. Though some of the travelers were familiar with the COTA paratransit system, few used it on a regular basis. Therefore, no participants were travelers who had used COTA paratransit service prior to joining the project.
- COTA reached out to its paratransit riders to try and find potential subjects for the research. None of the paratransit riders were interested, possibly due to disinterest in change and in new technology. Paratransit riders are accustomed to door-to-door service and scheduling via a call center to make their trips, and it was difficult to convince them to change.
- While initially it was thought that the pool of COTA paratransit riders would be a good pool of individuals from which to recruit, as the project team began engaging with businesses, government agencies, and organizations in this area, the team found much greater interest from potential participants from these groups. These groups were not initially targeted with planned recruiting efforts but once engaged, most participants were identified through a connection to these groups. These groups also contributed greatly to the training of these participants even after recruiting concluded. The project did not initially identify the following additional stakeholders:
    - ARC Industries
    - OSU Aphasia Initiative
    - FCBDD
    - OSUWMC Assistive Technology Center

9.3.3. Challenges

9.3.3.1. RECRUITING

As discussed in **Section 9.3.2.1**, the main challenge encountered during this project was recruiting and consenting the target number of participants. The initial slow response was rectified by engaging additional groups (ARC Industries, the Aphasia Initiative) in collaboration with FCBDD to identify potential participants. The greatest success came from approaching potential participants who did not regularly use transit service prior to the study, which differed from the project team's initial assumption that the best candidates would be travelers who used paratransit services.[101] While making this change helped the project team meet its recruiting goals, it also affected the target outcomes from the project, as one key outcome was thought to be a demonstration of potential cost savings for COTA as the paratransit operator (from moving paratransit riders to a fixed route). This is not to say that benefits were not ultimately achieved; however, it is more

[101] *The recruiting/screening process used for this project did not elicit specific information regarding how many travelers qualified for COTA paratransit services.*

difficult to quantify the independence (for both the traveler and their caregiver) from moving from a shared personal vehicle trip to an independent fixed-route trip.

9.3.3.2. ATTRITION

In addition to the challenge of recruiting participants for the project, attrition for various reasons was an ongoing challenge during the time leading up to go-live, as people left the program for various reasons summarized in **Figure 9-6**.

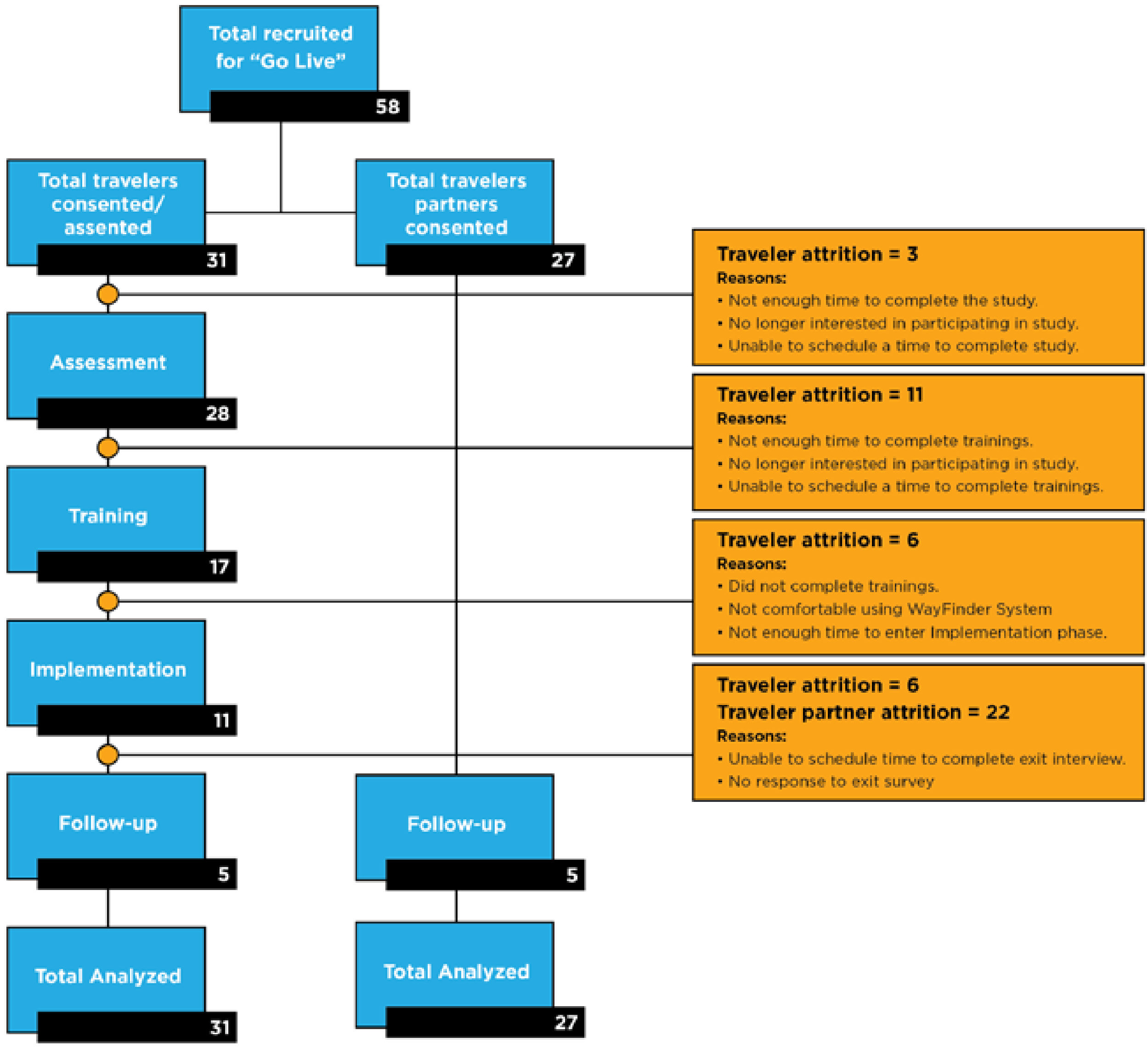


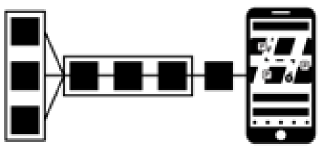
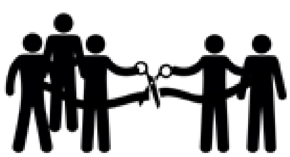
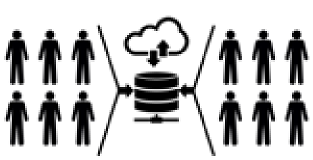
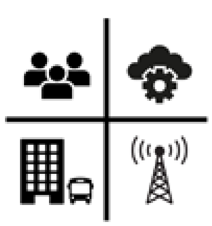
Figure 9-6: Study Attrition

Source: OSU

9.4. CONCLUSIONS, LESSONS LEARNED AND RECOMMENDATIONS

The MAPCD project addressed the City challenges presented in Columbus' smart city vision in using technology to expand transportation options for residents. The expectation was to introduce paratransit users to fixed-route bus service through the WayFinder application; however, the study found the key benefits were providing non-transit users with increased independence and confidence in using fixed-route service. The project addressed transportation challenges by deploying applications and strategies to meet the USDOT Vision Elements found in **Table 9-8**.

Table 45: Mobility Assistance for People with Cognitive Disabilities Project Relationship to USDOT Vision Elements

VISION ELEMENT #4 User-focused Mobility Services and Choices 	WayFinder enables persons with cognitive disabilities to travel with greater independence and autonomy. Phone-based GPS tracking allows WayFinder to safely guide users with step-by-step visual and audio instructions. The app also allows their caregivers to develop instructions based on the unique needs of their loved one. This solution gets participants from Point A to Point B safely using the bus, making it easier to independently make important trips like going to the grocery store or getting to work.
VISION ELEMENT #7 Strategic Business Models and Partnering 	The MAPCD project united stakeholders with the similar goal of connecting people with disabilities to jobs and services – helping them develop independence. This provides an opportunity to partner with public, private, and educational institutions including OSU, COTA, ARC Industries, FCBDD and AbleLink Technologies.
VISION ELEMENT #9 Connected, Involved Citizens 	The MAPCD project demonstrates an advanced technology that was used to enhance overall mobility for all residents including people with disabilities, enabling them to engage as an important engine of the future economy, independent of their caregivers. The Wayfinder application helped participants who didn't feel confident to use fixed-route bus service by providing navigation directions to, during, and from trips involving use of fixed-route bus service. This project not only deployed the wayfinding technology software (via a smartphone device) but established an interface and sharing of the project-generated data with the SCOC.
VISION ELEMENT #10 Architecture and Standards 	While all Smart Columbus projects were developed using USDOT's ARC-IT approach, with architectures generated using the Systems Engineering Tool for Information Technology (SET-IT) tool, the MAPCD project also represents using a product and technology developed through a previous USDOT effort (ATTRI) and replicating it for deployment with the research team and participants. This expedited the development process, as the team was able to create user needs and identify application enhancements outside of the traditional V-Model approach. It demonstrates how application of existing architecture and standards can be leveraged to accelerate future deployments.

Source: City of Columbus

9.4.1. Conclusions

While individuals with disabilities comprise nearly 20% of the U.S. population (and will continue to include an increasing number of older Americans),[102] many studies reflect the need to remove barriers to transportation options for people with visual, hearing, cognitive and mobility disabilities. The MAPCD project sought to demonstrate an enhanced option to assist people with cognitive disabilities with achieving mobility independence and increasing accessibility to fixed-route transit service.

Key datasets that were used to assess conclusions (including lessons learned) and performance measures (for mobility and opportunity[103]) included WayFinder application data as well as the traveler and caregiver surveys and focus group interviews.

Most conclusions with respect to this project relate to the underlying work to change traveler behavior:

- Changing traveler behavior is very difficult, especially when the baseline condition is relying on point-to-point transportation provided by friends, family or caregivers. Mobility independence may come at the expense of personal convenience for these travelers but is an essential element for helping them achieve equity in transportation. The primary benefit of the project was the increase independence, community participation, and autonomy for individuals with cognitive disabilities and this was validated by the mobility and customer satisfaction outcomes from the performance measure results. Specifically, the project addressed barriers encountered by individuals with disabilities. Some of these barriers include missing announcements of upcoming bus stops, automated stop notification not functioning correctly on fixed-route bus systems, or an inability to navigate public transit systems. While difficulties were acknowledged, the project also empowered these residents to receive and benefit from innovative technology and travel independently.

[102] *https://www.its.dot.gov/research_archives/attri/index.htm*

[103] *Smart Columbus Performance Measures for the MAPCD project also included agency efficiency, specifically an assessment of COTA paratransit operating expenditures. As previously indicated, the MAPCD project participants were not prior COTA paratransit riders.*

[11] *Davies, D.K. and Stock, S.E. (2021). Enhancing Independent Transportation for Individuals with Cognitive Disabilities and Others with Special Needs with the WayFinder Ecosystem: Final Project Report, Ford Mobility City:One Challenge, Michigan Central Station, AbleLink Smart Living Technologies, LLC, Colorado Springs, CO., February 28, 2021*

Wayfinder App Helps People with Vision Impairment Explore Central Ohio

Before joining the study, José relied on his family, caregivers, or the paratransit system to help him get around. After going through training on how to ride the bus and how to use the Wayfinder app, Columbus is José's oyster. **"It was a great experience because it provides directions and listening to the audio; it tells me what bus to get on and what stop to get off to go places like the North Market. You get to taste all different foods from different parts of the world like I'd never had before. It can help, not just me, but everyone, get around Columbus faster, more directly, and get to know the city to make it more fun and have good experiences."**

José, Mobility Assistance for People with Cognitive Disabilities participant, Clintonville

- The MAPCD project was unable to recruit paratransit users; COTA's paratransit clients were difficult to convince to use the new technology and to change from the door-to-door system provided. However, other pilots have had success transitioning WayFinder users to fixed-route service. For example, in a recently completed pilot project with the Detroit Department of Transportation, 80% of study participants were able to successfully transition to the fixed-route system, with an estimated annual cost savings to paratransit of $4,475 per individual using WayFinder to support fixed-route use.[104]
  - While the project team envisioned cost savings and agency efficiency benefits related to COTA paratransit services, the results indicate that the value-added component is the increased independence, community participation and autonomy. Therefore, the value may be realized by local, regional and state organizations that focus on vocational opportunities for individuals with cognitive disabilities, in particular individuals with developmental disabilities. This was recognized in the FCBDD's involvement in the MAPCD project, and the implementation of a similar programs throughout the U.S. including the Cuyahoga County Board of Developmental Disabilities (Cleveland area).
- Technology solutions such as the WayFinder product are one aspect of implementation; while the MAPCD project demonstrated individual cases of success and satisfaction in terms of improving access, mobility and independence, widespread adoption (and therefore sustainability) will require coordination with transit agencies and community service organizations. Transit agencies ensure access to GTFS and travel training facilities, while community service organizations ensure access to the resources and personnel that are necessary for successful implementation.

[104] *Davies, D.K. and Stock, S.E. (2021). Enhancing Independent Transportation for Individuals with Cognitive Disabilities and Others with Special Needs with the WayFinder Ecosystem: Final Project Report, Ford Mobility City:One Challenge, Michigan Central Station, AbleLink Smart Living Technologies, LLC, Colorado Springs, CO., February 28, 2021.*

- The satisfaction of participants is two-sided. The MAPCD project involved both the travelers and their caregivers. The project findings indicated that these two sides are not always aligned in terms of satisfaction and perceived benefits, as revealed in conflicting survey results from these two groups. This industry should continue to explore indicators that can accurately describe success from both sides. Mobility independence (and therefore connections to jobs and opportunity – vital to the economic vitality of these travelers) can be achieved, but it requires a commitment of time, ability and willingness from all stakeholders who contribute to the individual's care and well-being to achieve it. This can be a difficult trade-off in terms of convenience.
- A robust and flexible training plan improves success and satisfaction, and it may enable more independence. Modifications may be needed to the training protocol to make the training as effective as possible for each individual.

9.4.2. Lessons Learned

The following lessons learned from the MAPCD project could benefit other entities considering deployment of an assistive wayfinding solution.

- **Stakeholder engagement is critical –** This should be recurring throughout the project as this serves to define the use case and solution. In the case of MAPCD, the original use case was thought to be moving paratransit customers to a fixed-route; however, as potential participants were identified and evaluated for inclusion in the project, the use case pivoted toward traveler independence, community participation, and autonomy. This finding was identified by engaging with stakeholders who had a similar goal of connecting people with disabilities to jobs and services – namely ARC Industries, whose mission is to help people with disabilities achieve their life goals by supporting individuals as they access the community where they live and work, helping them develop independence, self-advocacy and skills important to employment and community membership.[105] Connecting with stakeholders who share the project vision was a key to clear documentation of needs and requirements.
- **Be inclusive –** Once the use case was broadened, the team benefited from removing generalizations and limitations that had initially bound recruiting. The project team found that by casting a wide net to identify potential participants allowed them to find and benefit from recruiting opportunities that were not initially identified. Additionally, the recruiting and consent process was applied in a manner where this more diverse pool of potential participants could self-sort, again removing the requirement for more strict screening parameters.
- **Develop a thorough training program –** The project team learned that the training for travelers was more labor intensive than initially anticipated and also required flexibility to accommodate the varying degree of experience (both with smartphones and transit in general, and more specifically with smartphone apps). Additionally, the team planned for the training to accommodate both the travelers and their caregivers. The training approach was modified during the project to adapt and become more flexible. In some cases, content had to be added to familiarize travelers with smartphone use while for others, certain training topics were eliminated based on the participants' experience and level of familiarity. In addition, the importance of including travel training professionals from human services agencies (e.g., ARC Industries, FCBDD, etc.) that are familiar with the training strategies and practical aspects of using public transit for helping individuals learn to ride public transit is critical for maximizing the effectiveness of technologies such as WayFinder.

[105] https://arcind.com/about-us/

- **The traveler and travel partner relationship is critical –** Once the 'right' combination of traveler and travel partner attributes, skills, and experiences are achieved, the results can exceed the anticipated outcomes. In the case of the MAPCD project, not only did the project result in travelers using the app independently, it also found that the consistent use of the app enabled some participants to travel completely independently on certain trips, not requiring the use of the app for wayfinding at all. It should also be noted that the participants' success (as defined by use of the application to complete trips) did not tie directly to demographic information such as the individual's type of disability. Success again was tied to the attributes, skills, and experiences of both the travelers and their caregivers.

9.4.3. Recommendations

The most informative recommendation from the MAPCD project is the need for projects like these to find partners with a shared vision. Initially, it was thought that the needs of a transit agency, and a need to reduce paratransit operating expense, would align most directly with the needs to increase mobility and opportunity for travelers with disabilities. Ultimately though, this goal is perhaps too broad when considering the relatively small percentage of travelers who require these services. The MAPCD project found greater success after partnering with businesses and organizations, such as ARC Industries, whose goal was completely aligned with those of the project.

Right-sizing the application of systems engineering practices can also help with efficient delivery of projects. In the case of MAPCD, the investment in wayfinding applications by USDOT through its ATTRI grants and the subsequent availability of off-the-shelf products allowed the team to focus its engineering efforts on the enhancement of the application and integration of the solution into the specific MAPCD use case. There are instances where full definition of user needs, requirements and system design are needed, but in the case where there are known solutions/products available, the deployment effort should focus on identifying and integrating the application into existing operations by focusing on identifying user needs, evaluating if enhancements are necessary, and adequately testing the results of both additional development and the satisfaction of the original user needs.

Expansion of the project to additional travel training agencies and significantly more individuals with disabilities in need of learning how to use the fixed-route system is a logical next step. For example, use of the WayFinder ecosystem components and services can be expanded for implementation over a multi-year project throughout greater Columbus focused specifically on the transition of current paratransit riders to the fixed-route system. A WayFinder implementation project could be determined based on the needs of stakeholders and the level of interest in building upon the MAPCD Project, as well as interest from travel training agencies serving individuals with disabilities throughout central Ohio.

Finally, regarding recommendations for successful and sustained adoption, direct alignment of goals and objectives among project partners will drive greater success. This is a topic that is still being evaluated by OSU, but the findings have helped identify potential models for delivery and implementation of technology wayfinding solutions. The first step is to understand who should own this type of solution; it probably should not be the transit agency as originally thought when the team began the user needs process. Rather a human service agency or even an advocacy group that directly seeks to resolve challenges for these individuals may have a greater platform to deploy, operate, and maintain this solution. COTA is supportive of clients using such platforms, but implementing a platform is not the intent of COTA paratransit services. Second, the deployment team and potential owners should understand and align on what drives the decision-making regarding both agency and traveler adoption of the application. For example, Cuyahoga County Board of Developmental Disabilities is focused on identifying marginal people who cannot currently travel on public transportation and having WayFinder support them. The ultimate goal is having them be able to travel on own. Last, the owner should also consider multiple models for operations and maintenance, which include the goal of travelers using the application as a tool for ultimate travel independence, where wayfinding is not needed.

Agencies using the WayFinder ecosystem have previously documented the following results:

- Significant increases in ridership of the fixed-route system (110% increase from baseline)
- Reduced use of paratransit
- Agency cost savings due to less staff time and mileage expenses providing travel directly to residents.[106]

Another Wayfinder project with Michigan Central Station indicated success not only related to these objectives, but also in the percentage of participants who would have been dependent on paratransit, human service agencies, and family to meet their travel needs that were able to successfully learn how to ride the fixed-route bus independently. As with the MAPCD project, none of these individuals had ridden public transit alone before using WayFinder.

In addition, individuals in this project using WayFinder as part of their travel training activities showed a statistically significant increase in vehicle identification skills (p=.008), Street Crossing Skills (p=.001) and Community Social Skills (p=.044).

The majority of study participants (87%) also reported that with the WayFinder app, they would be able to use fixed-route buses more and thus rely less on their travel partner or family members to meet their personal transportation needs. Expanded implementation of the WayFinder technology in the Columbus area should target the inclusion of both organizations currently providing travel training services to individuals with cognitive disabilities as well as specific inclusion of existing paratransit users to be able to more completely investigate the benefits that can be realized by COTA through widespread implementation of specialized travel support technologies such as the WayFinder system.

9.5. SUMMARY

The MAPCD project performance measures results demonstrated that the WayFinder application successfully improved the feeling of independence and comfort with using public transit for travelers with cognitive disabilities. This was quantified by the high satisfaction rating for both the application and the robust training program that was provided. There was a notable hesitancy for both travelers and their caregivers to use new technology and change travel behavior, which other agencies should note as a barrier to scale-up and adoption, but future awareness and training strategies can be leveraged to overcome these barriers. Perhaps unexpectedly, none of the participants were prior paratransit users; this meant that all 82 trips that were completed in demonstrated represented a new independent trip the participant was able to take without his or her caregiver or family member having to provide transportation; this embodies the Smart Columbus Program's desire to enable residents to live their best lives through innovative transportation.

The City, OSU and COTA are engaging with agencies and organizations that support those with cognitive disabilities to encourage current champions such as ARC Industries and the FCBDD – the same champions who played a key role in the recruiting and adoption for the project – to maintain and support the program going forward so that the learnings of this project may inform future service delivery to this population. To assist in this transition, OSU has developed a detailed training plan and COTA will provide its training facilities to assist the champion agencies/organizations moving forward. AbleLink Smart Living Technologies will provide ongoing support for the WayFinder app after the demonstration period. OSU and AbleLink will also publish detailed research findings.

The outcomes of the project were exciting – providing complete independence for travelers who had previously not used transit service and providing sufficient training to give these same travelers the

[106] *Mullen & Hoelzel. 2012.*

confidence to use fixed-route transit even without the wayfinding technology. These indications demonstrate the effectiveness and flexibility of the solution. Wayfinding technology can lead the path to complete independence for some travelers while also building the confidence of the traveler who will continue to need that guidance to travel independently. The MAPCD project is an example of people and technology coming together, as the researchers, caregivers and trainers played an equally important role in successfully developing and demonstrating the technology.

Chapter 10. Prenatal Trip Assistance

10.1. PROJECT OVERVIEW

As far back as the initial Smart City Challenge application, Columbus identified that there could be a link between reliable and safe transportation and medical outcomes, especially when it comes to Columbus' most vulnerable.

Concerns regarding high rates of infant mortality are not new to Columbus. Mayor Andrew Ginther previously created an initiative called CelebrateOne to combat infant mortality because every baby deserves to celebrate his or her first birthday, regardless of race, address, or family income. CelebrateOne is a place-based, collective impact initiative to reduce infant mortality and improve health equity so more babies reach this important milestone in Columbus and Franklin County. In analyzing patterns of infant deaths in the county, CelebrateOne found that the majority of deaths were occurring in eight "hot spots," all of which were impoverished neighborhoods. More than half of infant deaths were related to prematurity, with birth defects and sleep-related deaths being the other most frequently identified causes. These eight neighborhoods with a history of high infant mortality became CelebrateOne's program focus and are shown in **Figure 10-1**.

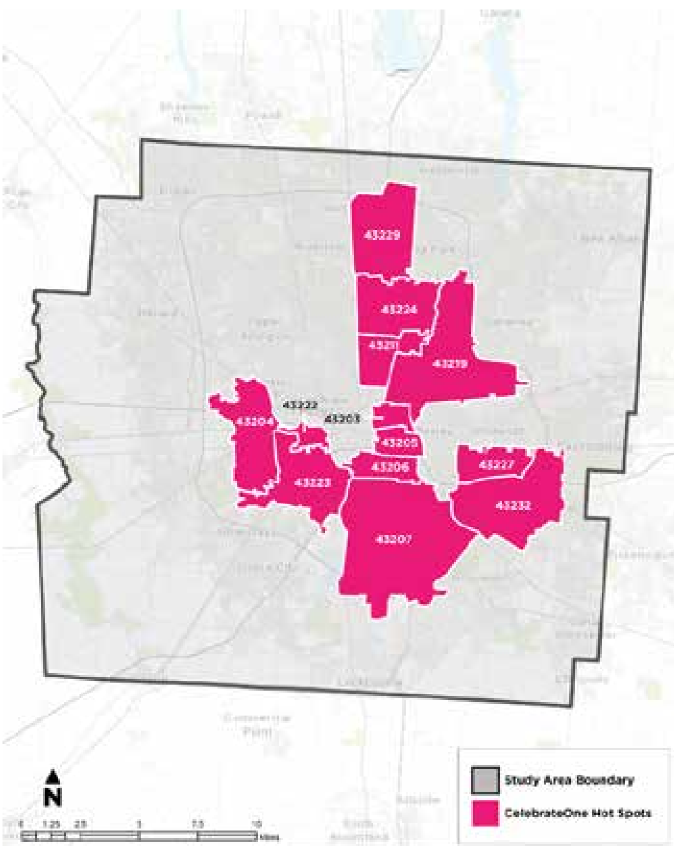


Figure 10-1: Geographic Scope of the Prenatal Trip Assistance Project

Source: City of Columbus

The Prenatal Trip Assistance (PTA) project focused on non-emergency medical transportation (NEMT) services delivered by Ohio's Medicaid Managed Care Organizations (MCOs) to study if changes in NEMT services can impact premature birth and therefore, lower the rate of infant mortality. Infant mortality is defined as the death of an infant before age one and is considered to be a global indicator for population well-being.

Columbus makes up the majority of Franklin County and Franklin County's infant mortality rate in 2017 was 8.2 deaths per 1,000 live births. When the project concept began in 2017, there were approximately 19,000 births and approximately 155 infant deaths. Additionally, in 2017, 2,300 or 10.4% of the total births were premature.[107] Prematurity is the leading cause of infant death in Franklin County. **Table 10-1** compares the local, county, state and national infant mortality rates.

Table 46: Infant Mortality Rates (Infant Deaths per 1,000 Live Births), 2017-2020

Year	Franklin County	CelebrateOne Zip Codes	Ohio	United States
2017	8.2	11.9	7.2	5.8
2018	7.6	10.6	6.9	5.7
2019	6.9	10.5	6.9	5.6
2020	6.6	9.8	6.6	not available

Source: Ohio Department of Health, Office of Vital Statistics, 2020

Smart Columbus developed a solution for an expanded and technologically advanced NEMT service. The solution allowed pregnant individuals to interact with an on-demand PTA System to schedule a ride through three flexible options: a website, a smartphone mobile app or a call center.

10.2. DEPLOYMENT SUMMARY

CelebrateOne has been a strong partner in the PTA project. As project planning commenced, CelebrateOne was engaged to identify stakeholders and systematically meet with all major constituent groups to hear concerns about the current state of NEMT in Columbus and to gather ideas. A series of focus groups were conducted with pregnant individuals to assess their satisfaction and concerns regarding NEMT services.

Through these meetings and focus groups, the project team identified the following gaps as opportunities for enhancements:

- Scheduling NEMT transportation services provided by MCOs is only available by phone. With limited cell phone minutes on most plans and possible long wait times, call centers as the only option are not ideal.
- Arrival time for pickup of the pregnant individual from both the home and the medical appointment can be challenging. There are windows of time within which the individual must be available to be picked up from home which could be considered long and without access to real-time driver location, can catch a traveler off-guard. For example, changing a baby's diaper or being in the middle of feeding time. The individual may also be dropped off well in advance of the appointment or wait a considerable time to be picked up from the medical appointment for the return trip home. The MCOs

[107] *Babies are considered premature if they are born before 37 weeks gestation or less than 5 pounds at birth.*

have established acceptable time allotments for each of these activities but anecdotally both pregnant individuals and medical office staff relay that the mobility providers do not always follow the rules.

- Most pregnant individuals are not provided with the driver's first name or the make, model and color of the car that is picking them up. This feature would provide an extra level of security.
- No mobility provider has car seats for children. A pregnant individual would need to bring a car seat, carry it into the medical appointment and then take it back home again. Each time, the pregnant individual is responsible for installing and removing the car seat.
- Providing feedback is not always easy and convenient for either the pregnant individual or the driver and MCOs would like that information in a timelier manner.
- Columbus heard from pregnant individuals that all these issues have led to frustration and for some individuals, ultimately led to the decision to not go to their medical appointments.

As the project team reached out to stakeholders, it became clear that engagement of subject matter experts for assistance in designing the PTA evaluation project was necessary. The project team reached out to partners at The Ohio State University Wexner Medical Center (OSUWMC) and were connected with two of its leading perinatal researchers, a reproductive epidemiologist and a women's health-focused biostatistician. While initially the team was planning a pre/post research design, the OSUWMC researchers advised that a randomized controlled trial (RCT) design would be preferable. Given the numerous ongoing efforts to decrease infant mortality in the county, there was concern about the interpretability of the pre/post design. Thus, it was decided to plan an RCT with pregnant individuals being randomly assigned to usual NEMT from their MCO or the enhanced on-demand NEMT. The OSUWMC researchers designed and implemented the study with input from project partners. The OSUWMC researchers also handled all regulatory and compliance issues, including but not limited to Institutional Review Board (IRB) submissions, and independently analyzed the study data.

After finalizing the study design and developing the data collection and analysis plan, the project team presented the idea to the Medicaid MCOs operating in Franklin County. While all expressed support for the project, participation for some MCOs would not be efficient as they had too few members in Franklin County. After lengthy discussions with each MCO, ultimately the project team decided to partner with CareSource and Molina Healthcare of Ohio (Molina), as combined these organizations care for nearly two-thirds of those covered by Medicaid in Columbus.

The project team worked closely with partners to develop a solution for an expanded, technologically advanced NEMT service. The solution would allow pregnant individuals to interact with an on-demand PTA System to schedule their ride through three flexible options: a website, an app on a smartphone, or a call center. The PTA System would connect the NEMT mobility providers who were responsible for providing the NEMT service to the pregnant individual. In an effort to design an intervention to meaningfully impact infant mortality, the project team decided to expand the provision of trips to additional pregnancy support categories including food bank, grocery store and pharmacy-only. Also, in an effort to provide additional assistance, the project team incorporated an innovative car seat solution with a local transportation partner to offer car seats for on-demand rides, which could be used for the intervention group infant(s) after delivery or siblings, as needed. Ohio law does not currently require the use of car seats in taxis or transportation network company (TNC) vehicles; so this was an added intervention benefit. The project team conducted a request for proposals process to identify a project transportation broker and selected Kaizen Health as the solution provider.

10.2.1. Systems Engineering Approach

The PTA project team started by executing a V-Model systems engineering approach. To kick off user need collection, Sidewalk Labs, an in-kind partner, conducted subject matter research and created a strategy plan focused on identifying and defining local stakeholder needs. The strategy plan was used as a base to write the project's Concept of Operations (ConOps). After the ConOps, the PTA project pivoted to a Hybrid approach for systems engineering by taking the defined stakeholder requirements and communicating them through the project's request for proposals. This shift to a Hybrid approach was due to the existence of well-established solutions in the NEMT market. The various approaches to systems engineering are described in **Chapter 2, Section 2.1**.

Kaizen Health was contracted to deliver the project under an Agile methodology for continuous development and delivery cycles but with a requirement for testing. **Figure 10-2** shows how the system design along with the implementation phases are unique. One of the main objectives in developing the master test plan was to integrate the development efforts of Kaizen Health and the testing efforts of the Smart Columbus team (within the Hybrid approach) and make clear the expectation and processes for how the City of Columbus would verify each feature, through each channel, and validate the system was developed as communicated, meeting those quality standards.

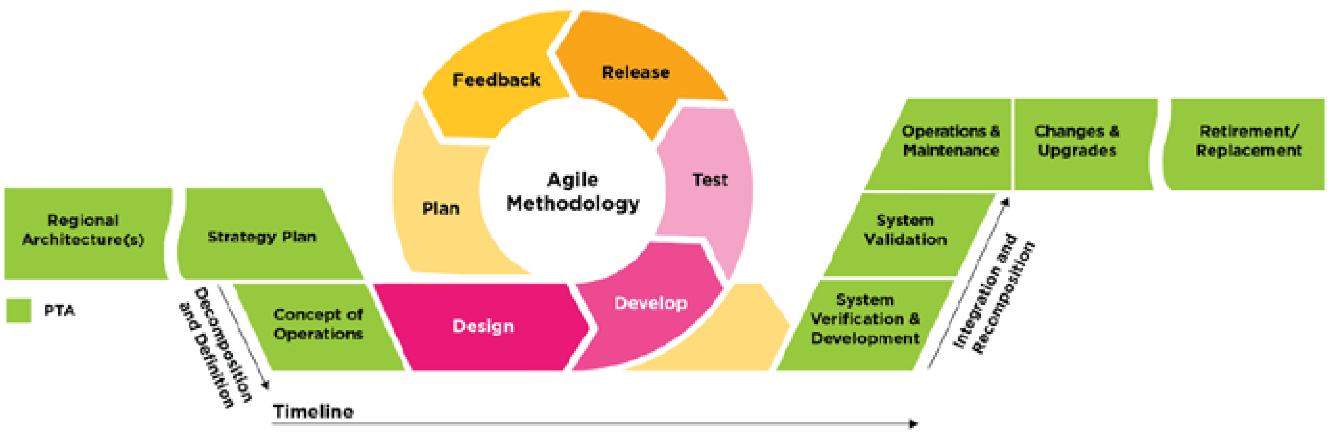


Figure 10-2: Systems Engineering Approach for Prenatal Trip Assistance

Source: City of Columbus

The master test plan was assembled following the IEEE 829-Standard for Software and System Test Documentation, which offered flexibility to meet the unique needs of the hybrid "Agile within V" processes that the project team followed. The testing itself was done in an Agile way. The test team would test, document the results, provide the feedback to the vendor, develop and implement changes to the application, and then retest if necessary.

Figure 10-3 summarizes the general timeframe for the project as it relates to major activities.

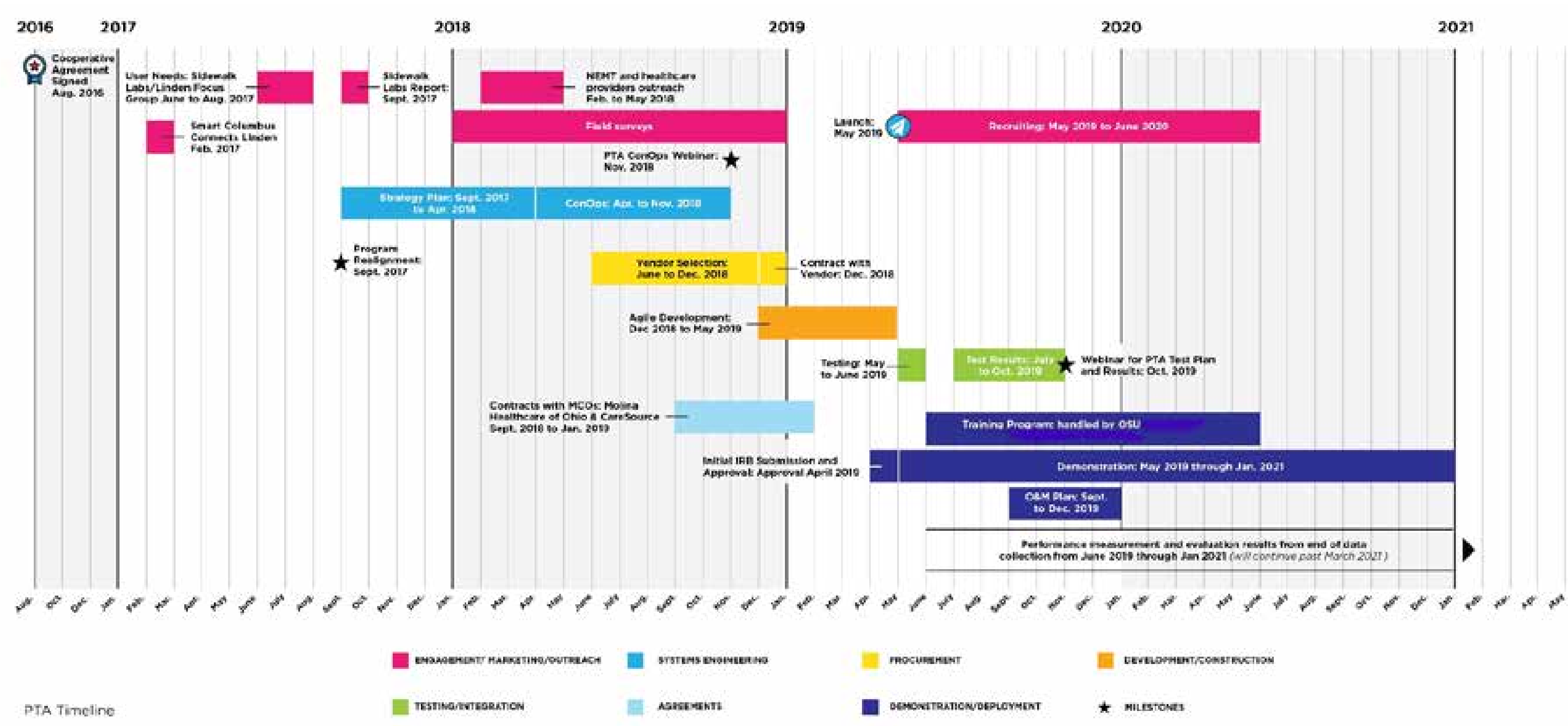


Figure 10-3: Timeline for Prenatal Trip Assistance

Source: City of Columbus

10.2.2. Study Aims

As mentioned previously, the project team elected to employ an RCT study design to evaluate the PTA project, named Rides4Baby. The primary aim of this RCT was:

- *To examine pregnant individuals' satisfaction with transportation services in those assigned to the intervention group [enhanced "smart" transportation (EST)] compared to those assigned to usual care group. For the purposes of this trial, EST was defined as: (1) access to on-demand transportation; (2) knowledge of real-time driver location and arrival time; (3) enhanced capabilities for patients to schedule pregnancy-related trips (call center, web portal, and mobile app); (4) increased communications between NEMT mobility provider and patient; and (5) flexibility for standalone trips to the pharmacy and food services.*

The secondary aims were:

- To examine adequacy of prenatal care as measured by the APNCU (Adequacy of Prenatal Care Utilization) Index between groups
- To examine the proportion of preterm delivery (< 37 weeks) between groups
- To describe and examine the proportion of infant mortality between groups

10.2.2.1. RECRUITMENT

Potentially eligible pregnant individuals were recruited by a number of sources, including:

- Referrals from StepOne, a community pregnancy support service provided by Physicians Care Connection
- McCampbell Hall Obstetrics and Gynecology Clinics at OSUWMC
- Franklin County Women Infants and Children (WIC) Clinics
- Direct mailing from the MCOs
- Moms2B, a community pregnancy support organization

StepOne is a pregnancy support hotline partially funded by CelebrateOne that pregnant individuals are encouraged to call if they need assistance being connected with prenatal care or other supportive services. During the course of its normal business, StepOne collects demographic information from individuals to assess their eligibility for various services.

If during that routine screening process a pregnant individual was found to meet the prescreening eligibility criteria for the Rides4Baby program outlined in **Table 10-2**, StepOne staff informed them that they might be eligible for a new transportation project. If the pregnant individual was interested in learning more, StepOne staff asked them to sign an electronic release of information form to permit StepOne to send their information to Rides4Baby staff at OSUWMC. The OSUWMC staff then contacted the pregnant individual, explained the study, and if the pregnant individual was interested, completed the screening process. In an effort to increase the number of pregnant individuals who called StepOne during the study period, the two Medicaid MCOs participating in the project (CareSource and Molina) sent postcards to individuals of reproductive age residing in the target areas of Franklin County encouraging pregnant individuals to call StepOne to see if they were eligible for the transportation project. A variety of advertisements were also placed in strategic locations (e.g., churches, WIC clinics) in the targeted communities and ads were run in local newspapers encouraging pregnant individuals to call StepOne. WIC sent a text message advertising the study to all their potentially eligible clients. Social media ads were also run by study partners.

Table 47: Eligibility Criteria

Prescreening Inclusion Criteria*	Final Screening Exclusion Criteria**
Pregnant and < 32 weeks of gestation	**No plans to move out of Franklin County prior to delivery**
At least 18 years old	Able to read, understand and communicate in English
Enrolled in CareSource or Molina for Medicaid services	Individual has not been previously enrolled in Rides4Baby
Residence in Franklin County, Ohio	Ÿ Race/ethnicity stratum not full Ÿ Willing to meet staff to be interviewed Ÿ Access to a telephone (mobile or landline), tablet or computer
Ambulatory	Willing to consent to communication by phone, text, and email
English speaking	Last menstrual period date on or before 02/09/2020 (due date on or before 11/15/2020)

**Assessed by StepOne*
***Prescreening criteria confirmed by OSU along with final screening criteria*
Source: City of Columbus

Prior to the COVID-19 outbreak, study investigators established recruitment onsite at Franklin County WIC Clinics, the OSU Obstetrics & Gynecology Clinics, and at Moms2B. Rides4Baby staff screened pregnant and interested individuals at WIC Clinics and if possible, completed the enrollment process that day.

Rides4Baby staff recruited on-site in the OSU Obstetrics & Gynecology Clinics in McCampbell Hall. With the assistance of clinic research staff, Rides4Baby staff identified pregnant individuals who were < 32 weeks of gestation to approach regarding the study. If the potential participant was interested, screening for eligibility was completed. If the pregnant individual was eligible and able to stay after the prenatal appointment, Rides4Baby staff completed the enrollment process that day. Otherwise, arrangements were made for Rides4Baby staff to meet the potential participant at a library near their home to complete enrollment.

In addition, Rides4Baby staff recruited at Moms2B, a community-based pregnancy support program within the Department of Obstetrics and Gynecology at OSU that operates in eight neighborhood sites throughout Columbus. Recruitment procedures at Moms2B were similar to those used at the clinic. Interested pregnant individuals were screened for eligibility. If they were eligible, the enrollment process was completed that day if the potential participant was able to stay after the regular Moms2B session. If the pregnant individual could not stay, alternative arrangements were made to complete the enrollment process.

10.2.2.2. INFORMED CONSENT AND RANDOMIZATION

Rides4Baby staff scheduled an in-person baseline interview with pregnant individuals who screened as eligible and were interested in participating. Rides4Baby staff confirmed the interview date and time in advance of the appointment to remind the pregnant individuals to attend. Pregnant individuals who did not wish to meet in person to conduct the interview or who no-showed three times for the enrollment interview were considered ineligible for participation. If a pregnant individual was found to be unable to get to one of the Rides4Baby interviews due to lack of transportation, a free bus pass was provided to assist in making the trip.

Before proceeding with enrollment, Rides4Baby staff reviewed the informed consent document with the potential participant and gave them an opportunity to ask questions. Once the pregnant individual had all questions addressed, they were asked to sign the combined informed consent and parental permission (i.e., permission for the unborn infant) document. Pregnant individuals were asked to sign the informed consent document in REDCap, a secure, web-based application for building and managing online surveys and data collection forms, and then provided a printed copy for their records. After verifying all eligibility criteria listed in **Table 10-2**, the new participants were randomized immediately after completing the baseline interview and were provided training in how to schedule a ride according to their assigned group.

10.2.2.3. INTERVENTION

As mentioned previously, the randomized trial included two arms: (1) the usual care group with usual care provided by the MCOs and 2) the intervention group receiving EST services. Participants randomly assigned to the usual care group received the typical transportation services from their MCO. Specifically, participants were advised to call their MCO transportation center to arrange a ride, as needed, per the usual procedures. Participants randomly assigned to the intervention group were asked to use Kaizen Health rather than their MCO if they required transportation services. Participants in the intervention group could schedule rides via the Rides4Baby mobile app (**Figure 10-4**), web portal or via telephone to a call center.

Table 10-3 provides a detailed description of the transportation services provided to participants in the usual care and intervention groups. The usual care information is based on when the study started.

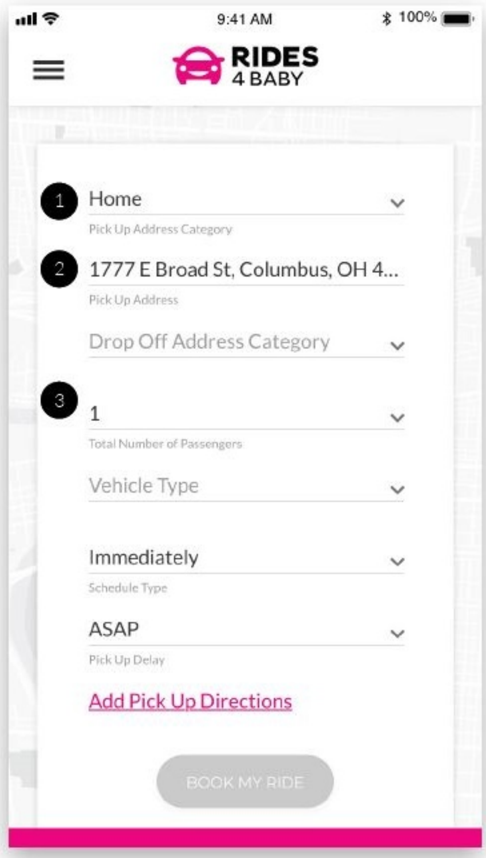


Figure 10-4: Rides4Baby Mobile Application

Source: Rides4Baby

Table 48: Comparison of Transportation Provided in Each Study Arm

	Molina Usual Care Transportation	CareSource Usual Care Transportation	Intervention Transportation
Mode of trip scheduling	**Call center**	**Call center**	Ÿ **Mobile app** Ÿ **Web portal** Ÿ **Call center**
Trip scheduling timing	Ÿ Standard 2 business days in advance Ÿ Emergency Arranged the same day	Ÿ Standard 2 business days in advance Ÿ Emergency Arranged the same day	Ÿ On-demand Ÿ Advance scheduling
Permissible trip types	Ÿ Health care visits Ÿ WIC office visits Ÿ Medicaid redetermination appointments Ÿ Pregnancy support services Ÿ Pharmacy visits permitted when returning from health care visit	Ÿ Health care visits Ÿ WIC office visits Ÿ Medicaid redetermination appointments Ÿ Pregnancy support services. Ÿ Pharmacy visits permitted when returning from health care visit	Ÿ Health care visits Ÿ WIC office visits Ÿ Medicaid redetermination appointments Ÿ Pregnancy support services Ÿ Freestanding pharmacy trips Ÿ Grocery store and food bank trips
Pickup and drop-off location validation[a]	Performed by call center	Performed by call center	Checked automatically against a pre-approved list provided by the MCOs
Trip number limits	30 one-way trips per calendar year[b]	30 one-way trips per calendar year[b]	One-way trips: Ÿ Heath care visits: 4 per week[b] Ÿ Health care after hours: 2 per month Ÿ Support services: 4 per week Ÿ Pharmacy (dedicated trip): 2 per month Ÿ Pharmacy (returning home): 2 per week Ÿ Grocery or food bank: 4 per month
Trip location limits	None, as long as destinations are MCO-approved	None, as long as destinations are MCO-approved	Trips limited to Franklin County and its contiguous counties

Mode of trip scheduling	**Call center**	**Call center**	Ÿ **Mobile app** Ÿ **Web portal** Ÿ **Call center**
Permissible travel hours	· 7am to 7pm · Support services: 24 hours all week · Exceptions made for medical services outside of those hours or where travel time dictates	Ÿ 6am to 9pm for health care trips; hospital-/ facility-discharge trips available 24 hours a day Ÿ Exceptions made for medical services outside of those hours or where travel time dictates	Ÿ 6am to 9pm for health care, pharmacy and support-services trips Ÿ Other: 24 hours a day
Return trip scheduling	Members call to schedule the return trip when ready to leave Based on initial travel mode, select cases could allow return trips to be scheduled via text Members can schedule their return trip during initial call	Ÿ Members can call to schedule the return trip when ready to leave Ÿ Members can schedule their return trip during initial call	Ÿ Members can click on a text received after first leg of their trip to obtain a return ride Ÿ Members can schedule via the mobile app, web portal or call center
Car seat(s) provided	No	No	Yes, upon request at the time of scheduling
Member trip tracking	None	None	Members can view trip details, including car and driver information in app before and during trip (also can see driver's car on in-app map feature)

Source: City of Columbus

[a] *List of approved health care facilities was the same for each arm.*

[b] *The MCO can approve additional trips if deemed medically necessary.*

10.2.2.4. STUDY OUTCOMES

As mentioned previously, the primary outcome for the proposed trial was overall satisfaction with transportation services as assessed by the final study questionnaire (i.e., two months after delivery or miscarriage). The satisfaction questions on the final questionnaire were adapted from a previously published transportation satisfaction survey (Bellamy, 2003). Responses for each domain and for the overall assessment of satisfaction included: very satisfied, somewhat satisfied, neither satisfied nor dissatisfied, somewhat dissatisfied and very dissatisfied. Individuals who indicate that they are either somewhat satisfied or very satisfied with their transportation services overall were considered to be satisfied for measurement of the primary outcome.

Secondary outcomes were assessed using Ohio vital records data. Adequacy of prenatal care was assessed with Kotelchuck's APNCU (Kotelchuck, 1994). The APNCU uses data regarding the month that prenatal care began and the ratio of observed to the recommended number of prenatal care visits based on American College of Obstetricians and Gynecologists (ACOG) guidelines to summarize the adequacy of prenatal care received. Individuals are grouped into one of four categories:

- Adequate plus: care initiated by the fourth month and 110% or more of recommended visits received
- Adequate: care initiated by the fourth month and 80-109% of recommended visits received
- Intermediate: care initiated by the fourth month and 50-79% of recommended visits received
- Inadequate: care initiated after the fourth month or less than 50% of recommended visits received

For the purposes of this trial, adequate or adequate plus care versus intermediate or inadequate prenatal care were examined.

Preterm birth was defined as any delivery occurring before 37 weeks gestation. Infant mortality was defined as death of a live born infant within the first year of life as measured using the linked live birth and death records. Exploratory outcomes included the number of trips taken and measures of every preterm birth.

10.2.2.5. DATA COLLECTION

The Rides4Baby baseline interview was conducted as soon as the informed consent document was signed. The baseline questionnaire queried participants about: previous pregnancies, number of prior preterm births (< 37 weeks), due date, educational attainment, self-rating of overall health, chronic medical conditions (e.g., hypertension, diabetes, sickle cell), access to a car, satisfaction with prior use of MCO transportation services, smoking status, marijuana use and opioid use, age, race/ethnicity, country where born, monthly household income, household size, address, best telephone number, type of mobile phone (basic versus smartphone), and the names and telephone numbers of individuals to contact if original contact information is not working.

Every 30 days following enrollment, participants were texted a link to an online form with several questions to assess use of and satisfaction with transportation services. These questions included: (1) "How many times did you use Rides4Baby transportation this month?"; (2) "On a scale of 1-5, how satisfied were you with that transportation this month?"; (3) "During any of your Rides4Baby rides this month, did you feel unsafe?"; and (4) "How many times did you use another form of transportation to get to the doctor or health care provider this month?". Participants who had taken no Rides4Baby trips in the previous month saw only the first and last questions.

Participants were asked to notify Rides4Baby staff when they delivered or had a miscarriage. As a participant reached the end of the third trimester, a reminder text was sent to remind them to call the Rides4Baby staff to share the actual delivery date. For participants who notified the Rides4Baby staff immediately of their delivery, staff offered to meet them in the hospital to bring them a gift (described below under **Section 10.2.2.9**). If, for whatever reason, Rides4Baby staff was unable to get to the new parent before they were discharged from the hospital, Rides4Baby staff provided them with their delivery gifts when they met them for their interview at eight weeks postpartum. For participants who miscarried, Rides4Baby staff provided them with all of their remaining remuneration when they met them for an interview at eight weeks after miscarriage. For all final interviews, a reminder text was sent in advance of that appointment to remind participants to attend. Self-reported data collection ceased at two months postpartum, if the participant was exited due to nonadherence, or if ten attempts to contact the participant (at varying days/times by phone, email, and text) failed. If, for whatever reason, the participant was unable to meet the Rides4Baby staff in person for the final interview, an attempt was made to conduct a shortened version of the interview over the phone and the participant's remaining gift cards were mailed.

Trip data were collected by Kaizen Health (the study transportation broker) as well as both Medicaid MCOs. Data collected included: the participant ID, number of trips taken, type of trip (destination), dates of trips, trip timeliness information, and adherence data (whether or not the trip occurred, was canceled, or was rescheduled). These data were incorporated into the study database for analysis.

Following delivery, the study team obtained pregnancy outcome data from the Ohio Department of Health. Specifically, the index vital records were obtained (i.e., birth, fetal death, and infant death certificates) for each participant to verify pregnancy outcomes. Participants were linked to their index vital records via a probabilistic matching procedure based on the parent's name, parent's date of birth, address, and child's date of birth or the miscarriage date. All record links were reviewed by the study statistical team for accuracy.

10.2.2.6. DATA COLLECTION DURING COVID-19

Due to the COVID-19 pandemic, beginning in mid-March 2020, all study interviews (i.e., the enrollment interview and the final interview) began to take place over the telephone. For enrollment interviews, potential participants were emailed a PDF copy of the informed consent/HIPAA document to review in advance. If the potential participant did not have access to email, a link to the documents was texted or a printed copy was mailed.

At the scheduled time, study staff called the potential participant, asked if the informed consent/HIPAA document was received (if not, the call was rescheduled), and reviewed the material over the telephone. The potential participants were then asked to provide their verbal informed consent for participation in the study. Study staff noted this information in the potential participant's file and the interview proceeded. Following the interview, if all eligibility criteria was met, the new participant was randomized and advised how to schedule rides according to the assigned group.

With regard to the final interview, participants were already provided the option to complete that interview via telephone and to receive their incentive via mail. Phone interviews were required in lieu of in-person interviews while the COVID-19 restrictions remained in place.

10.2.2.7. PARTICIPANT RETENTION

Rides4Baby staff employed several strategies to encourage participant retention. First, every effort was made to have participants continue to interact with the same staff member who enrolled them. Secondly, participants were sent follow-up surveys every 30 days and if they failed to respond to a given survey, study staff reached out to them. Finally, a birthday card was sent to the participants on their birthday to express that staff were thinking of them and appreciated their participation.

10.2.2.8. PARTICIPANT NONADHERENCE

Several types of participant nonadherence were anticipated during the trial. First, individuals in the intervention group could have taken a trip(s) to an unapproved location(s) either by finding a bug in the mobile app or the web portal. Individuals could also misuse the mobile app or web portal to travel to an approved location only with the intent of traveling to an unapproved location (e.g., might use the app to travel to a pharmacy near a friend's house). Finally, an individual could have been verbally (or physically) abusive with a driver or the call center staff.

In cases of nonadherence, study staff issued a warning to the participant (by phone, if the participant could be reached, as well as by email). If nonadherence continued after a warning was given, one of the following two consequences occurred:

- Participants in the intervention group were provided "call center only" access through the technology provider where they no longer had access to the mobile app or web portal.
- Participants in the intervention group were moved back to the "usual care" group of the study, so that their MCO could provide them with transportation.

10.2.2.9. PARTICIPANT REMUNERATION

To encourage active participation in Rides4Baby, participants received monetary and noncash incentives. For fully participating in the study, participants received $140 in grocery store gift cards. Each participant also received a large package of diapers after delivery.

During the COVID-19 pandemic, all study gift cards were mailed with tracking information as participants progressed through the study. Due to the large size of the package, diapers were delivered to participants when socially distant interactions were again permitted.

10.2.2.10. HUMAN SUBJECTS CONSIDERATIONS

This trial was reviewed and approved by the IRBs at both OSU (Biomedical) and the Ohio Department of Health. The project was also overseen by an independent data safety and monitoring committee.

10.2.2.11. DATA MANAGEMENT

Study data were collected and managed in a REDCap database located behind the firewall at the OSUWMC. All questionnaire data were entered directly into REDCap by study staff. Transportation data were to be provided by the study transportation broker and the MCOs and incorporated into the study database. The linked vital records for the index pregnancies were also included in the study database.

All data transfers between study partners were covered by data use agreements and were performed via secure FTP.

10.2.2.12. PROJECT LAUNCH

The study team designed a comprehensive recruitment strategy with the help of study partners. Project launch occurred on May 31, 2019. Recruitment, described above in **Section 10.2.2.1**, began with StepOne looking back at their records for the prior few months to identify

Figure 10-5: Community Partner Information Session

Source: City of Columbus

if pregnant individuals who previously contacted them were potentially eligible. If so, StepOne called the pregnant individuals again to determine interest and eligibility. The communications team orchestrated widespread literature drops at churches, hair salon and other community hot spots and social media and radio ads, which encouraged pregnant individuals to call StepOne to inquire about the project.

Figure 10-5 shows an image from the community partner information session held when Rides4Baby launched in June 2019. Social workers, community health workers, primary care and OBGYN office nurse managers, and social service organizations were invited to attend to learn about the study and to seek their assistance in recruiting participants. More than 100 people attended the session. Attendees received outreach materials for distribution including hotcards, flyers and a digital communications toolkit for use through their own outreach and communication channels.

10.2.3. Demonstration

Overall, a total of 4,120 pregnant individuals completed the initial screening for the study.

Between May 31, 2019, and June 30, 2020, 143 participants were enrolled and randomized in the Rides4Baby study. Of those participants, 72 were randomly assigned to the usual care group while 71 were randomly assigned to the intervention group. The final study visit took place on January 12, 2021.

The following paragraphs present selected characteristics of the participants enrolled in Rides4Baby. The median age of participants enrolled in the study was 26 years (range was 18 to 41). The study sample was racially and ethnically diverse, with 77% non-Hispanic Black women, 15% non-Hispanic white women, 8% Hispanic women and non-Hispanic women of another race. Eight percent of participants indicated that they were foreign born. Twenty-eight percent of participants reported having used NEMT in the past. Of these, approximately half (48%) indicated that they were either satisfied or very satisfied with the prior NEMT services that they had received.

Regarding pregnancy and health history, the majority of participants had a prior live birth (73%). Of those with a prior live birth, 28% reported having a prior preterm birth. The median gestational age at enrollment was 15 weeks or early in the second trimester. Overall, the study population was medically high risk. Among participants, 11% indicated that their general health status was fair or poor. There was a very high proportion of smoking in the three months before pregnancy: 36%. Participants also reported high proportions of depression and anxiety: 67% and 69%, respectively.

Overall, participants assigned to the usual care group took fewer trips than participants did in the intervention group. Over the study period, participants in the usual care group took a median of two trips whereas participants in the intervention group took a median of 19 trips. Of note, there were also more participants in the usual care group than intervention group who took no trips at all during the study period, 44% to 18%, respectively. For participants in the usual care group, 51% of trips were to a medical facility, 43% of trips were trips home, and 6% were trips to other residences. In the intervention group, 32% of trips were to a medical facility, 44% were trips home, 10% were trips to the grocery store or food bank, 5% were to the pharmacy, 3% were trips to support services, 4% were to other residences, and 2% were to other locations. While both MCOs began offering grocery store trips during the study period due to COVID-19, none of the study participants assigned to usual care took advantage of that benefit.

To evaluate the primary study aim, the study team examined the global satisfaction rating recorded at eight weeks postpartum (or study exit) for all participants who attempted at least one trip. There was a strong suggestion of increased satisfaction in the intervention group compared with the usual care group, with 90% and 79% reporting being satisfied or very satisfied, respectively.

Among 58 participants randomly assigned to the intervention group who used the mobile app to schedule a ride, 82.8% said that they would definitely recommend and 13.8% indicated that they would probably recommend the Rides4Baby mobile app to other pregnant individuals. With regard to overall satisfaction, 93.1% of users reported being very or somewhat satisfied with the mobile app. With regard to the ease of learning the mobile app, 98.3% of users were very or somewhat satisfied.

In examining the adequacy of prenatal care that participants received using the APNCU index, there was no notable difference in prenatal care use between groups, with 66% receiving adequate or adequate plus prenatal care in the usual care group versus 69% in the intervention group.[108] It should be noted, however, that prenatal care information was missing for 12 participants or 8% of the study cohort due to miscarriage or missing data on the vital records.[109]

With regard to preterm delivery, no meaningful difference was observed in preterm delivery between the usual care and intervention groups, with term birth proportions of 77% and 69%, respectively.[110] There were slightly more sets of twins (four) in the intervention group compared with the usual care group (two), which could influence the interpretation of this comparison, which will be examined in a sensitivity analysis. The final infant mortality data will not be available until January 2022 at the earliest; however, the investigators are aware of no infant deaths in the study population to date.

The demonstration ended on January 12, 2021, with the final study visit.

This project was time limited. The research and lessons learned are being evaluated by the OSU research team and will be published in research journals in late 2021 or 2022. Separately, each of the project's partner MCOs are reviewing the findings to see what aspects of the project's technology solutions will work for their NEMT delivery in the future. For instance, during this project, CareSource started to introduce additional methods for requesting an NEMT trip.

10.2.4. Communications

The communications team served to support the research team in recruitment for the PTA project.

10.2.4.1. STRATEGY

In order to achieve the recruitment goal, a multipronged outreach strategy was created to reach pregnant individuals where they are and motivate them to respond to the calls to action. Initially, the call to action was to contact StepOne to see if the pregnant individuals qualified for the study. The approach to work through an established service was deliberate. StepOne was well known in the community and the pilot could leverage that trust and name recognition to recruit pregnant individuals in a short amount of time. StepOne also provided additional pregnancy resources beyond transportation so a pregnant individual could receive multiple forms of assistance with just one phone call. StepOne would also continue to be funded post-study so outreach resources were used efficiently to support and leverage a long-term service in the community, rather than creating a short-lived hotline. The communications team reviewed recruitment numbers on a weekly basis and determined early on that additional means and methods of recruitment was necessary. A release of information form was required to be signed by the caller for StepOne to share contact information with OSU, which was a hurdle. Due to this challenge, the communications strategy shifted to promoting both StepOne and the OSU hotline in promotional materials. This change allowed for pregnant individuals who were just interested in the study to reach out directly to OSU, rather than go through StepOne.

Based on insights from CelebrateOne and its previous work in the target zip codes, the communications team knew that the small number of possibly eligible, potential participants would be difficult to reach for a

[108] *Risk difference = 3.1% (95% Confidence Interval: -13.0, 19.1)*

[109] *Risk difference = 11.9% (95% Confidence Interval: -1.1, 24.8)*

[110] *Risk difference = -7.7% (-23.0, 7.6)*

variety of reasons, from their degree of transience to people, in general, not responding to mail, email or phone calls unless received from someone they already know.

The communications team used an integrated, multichannel mix of traditional and digital paid advertising as well as direct engagement through influencers like the faith community, health care professionals, beauty shops and food pantries. This created a 360-degree effect, amplifying StepOne and increasing the likelihood of reaching eligible pregnant individuals. The strategy sought to interact with the target audience in multiple ways, multiple times to encourage them to heed the calls to action.

10.2.4.2. AUDIENCE AND KEY MESSAGES

Initially, the audience for recruitment was pregnant individuals who lived in CelebrateOne's hotspot zip codes who were enrolled in a CareSource or Molina Medicaid Managed Care plan, who needed transportation assistance. In the fall of 2019, recruitment criteria were broadened to pregnant individuals who lived in Franklin County, rather than just the eight hotspot zip codes.

Messaging was developed for the outreach channels described below based on target market research on emotional drivers, input from pregnant individuals and their trusted messengers such as social service agencies, MCOs and churches. Messaging was kept simple, with a call directing pregnant individuals to StepOne, as noted in the strategy (see **Figure 10-6**). The language level was written at a no higher than fifth-grade reading level as the average literacy level in the target zip codes is lower elementary school. Initially, messaging focused on communicating study criteria and asking pregnant individuals to self-identify whether they needed help with getting a ride to the doctor. It also asked pregnant individuals to provide feedback on their MCO transportation benefit because feedback from pregnant individuals in the focus groups indicated they thought they did not have an outlet to share their input.

After a few weeks of testing the initial message, adjustments were made to address the fact that many pregnant individuals were not self-identifying that they needed a ride. The final version of messaging promoted both StepOne and Rides4Baby independently to guide pregnant individuals directly to OSU. This also addressed the conversion challenge the release of information form created when targeted pregnant individuals called StepOne first. All messaging was developed in accordance with IRB standards. This meant language could not be overly promissory, imply benefits and or unduly emphasize the incentive. All participant-facing materials were submitted and approved by the OSU Biomedical IRB.

The key tactics to reach these audiences are listed below. These are divided into the different types of media used – paid, earned, owned and shared – as explained in **Chapter 3, Section 3.2.4**.

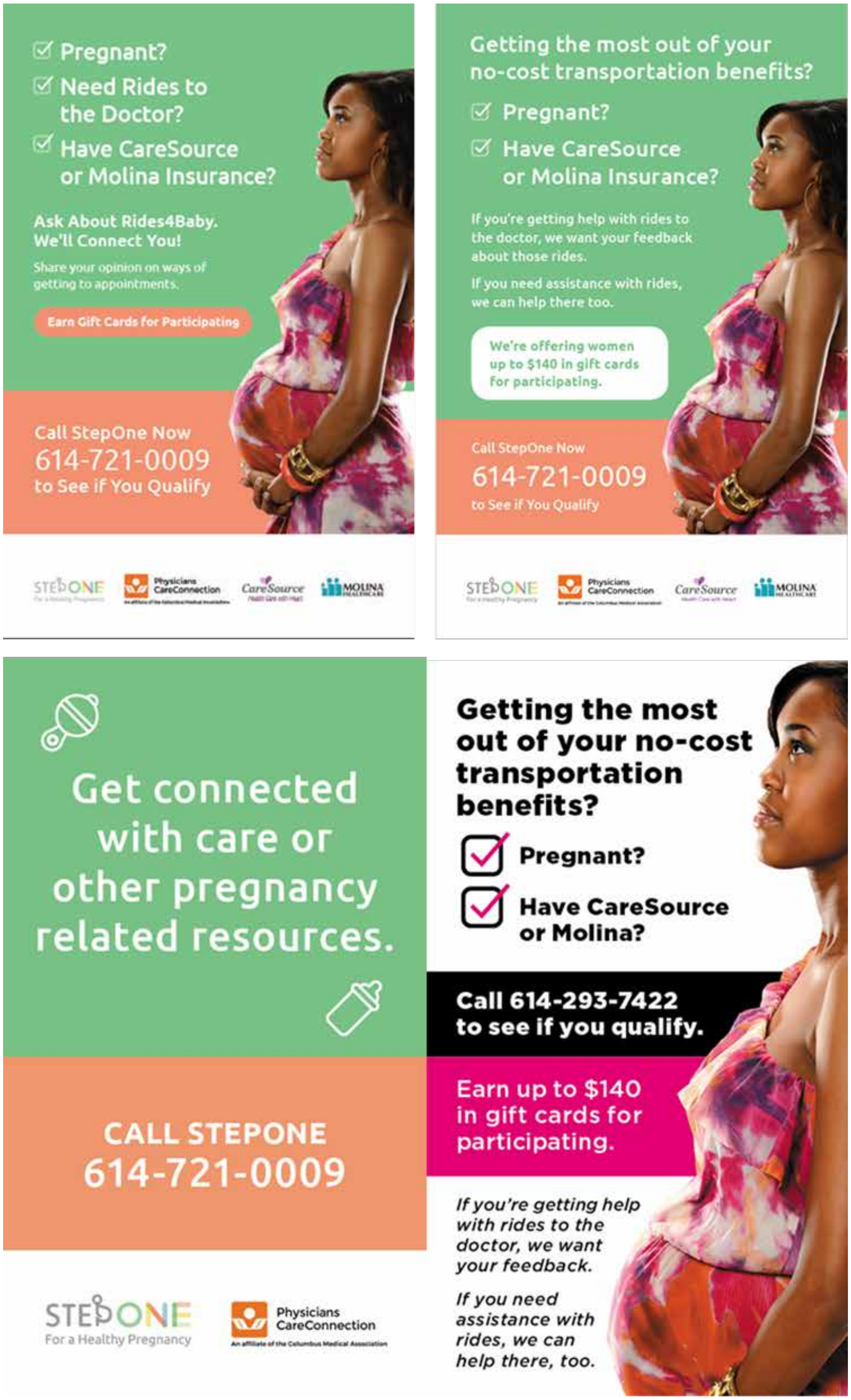


Figure 10-6: Three Versions of PTA Outreach Material

Source: City of Columbus

10.2.4.3. PAID

To support the research team's recruitment efforts, the communications team purchased advertising through a local media outlet, Radio One, which operates radio stations and social media platforms and hosts in-person community events. During the recruitment window, this included:

- 1,044 total on-air public service announcements
- Three live-reads on each of two radio stations each week for four weeks
- Two social media posts on Facebook and additional boosting of content over the course of 21 days to enhance the number of views that the post received
- 100,000 streaming impressions across three separate station websites
- Columbus Minority Communicator newspaper ad

This media buy resulted in an estimated reach of 300,000 impressions or interactions with the content.

10.2.4.4. SHARED

Working closely with selected partners, the communications team increased the volume of impressions that the recruitment materials received through shared messages with trusted organizations. These partners placed their branding alongside the existing recruitment materials to convey the call to action in a trustful manner.

- The Central Ohio Transit Authority (COTA) placed 100 placards inside 330 coaches
- Molina sent a dedicated mailer to 10,555 potential participants in their membership list
- CareSource sent a dedicated mailer to 961 potential participants in their membership list (see **Figure 10-8**)
- CelebrateOne distributed outreach materials at all events they attended and hosted such as community baby showers. The communications team distributed materials at locations prospective participants frequented such as houses of worship, childcare centers, community centers, libraries, beauty salons and barbershops, food resource locations and health fairs. One distribution occurred in conjunction with the launch of recruitment in summer 2019 and consisted of 86 locations receiving a total 3,260 pieces of material. A second round was conducted in January and February 2020 and consisted of a total of 93 locations receiving 4,350 pieces of material.
- As noted above, the City of Columbus hosted a community partner stakeholder session in June 2019. Over 100 people attended the session. Attendees received outreach materials for distribution including hotcards, flyers, and a digital communications toolkit with approved messaging and graphics.

Figure 10-7: Rides4Baby Bus Plaquard

Source: City of Columbus

Figure 10-8: Rides4Baby Managed Care Organization Mailer

Source: City of Columbus

10.2.4.5. EARNED

To protect the integrity of the research study, the communications team intentionally did not seek out earned media opportunities. Instead, the team strategically focused its efforts to support the research team via owned, paid and shared communications vehicles which allowed for the required level of control over the message received by a potential participant.

10.2.4.6. OWNED

The City of Columbus and project partners leveraged their own communication channels to distribute information to potential participants including:

- Rides4Baby webpage on CelebrateOne's website
- Rides4Baby study webpage on OSU's website
- Smart Columbus website and organic social media posts
- CelebrateOne organic social media posts (see **Figure 10-9**)
- Columbus public television crawl ads

Figure 10-9: CelebrateOne Facebook Post

Source: CelebrateOne

10.2.4.7. COMMUNICATIONS LESSONS LEARNED AND RECOMMENDATIONS

The project team identified the importance of communications early in the project. Project development and communications meetings were scheduled on a regular basis to develop, assess and modify communications, as needed. The following items were communications successes:

- Brought stakeholders to the planning table early and often: MCOs, City of Columbus, CelebrateOne, StepOne, and OSU's research design team met regularly with the Smart Columbus project team (including project management, engineering, legal and communications/engagement experts).
- Created a process flow chart to clarify roles and process; this allowed stakeholders to think through details and identify/resolve potential issue areas. The process graphic was revised repeatedly as complex issues were worked through.
- Used both top down and bottom-up approach to meet key deadlines: organization decision-makers were at the table early and often, but executive-level outreach to MCO directors and Ohio Department of Medicaid was also required to ensure endorsement and timely progress.
- Messaging was tested and revised based on performance and input from pregnant individuals.
- Educating partner agencies and providing them communications tools helped recruitment and increased community buy-in and awareness.

As with any project that requires community engagement, coordination with multiple stakeholders and participant recruitment, the project team offers the following lessons learned and recommendations:

- Fully understand the IRB requirements, process and timeframes for approvals. The IRB may require multiple edits and reviews of recruitment and communications materials, which extends the production schedule. The IRB may meet as often as a few times a week to as infrequently as once a month. This schedule will affect the ability to revise and optimize outreach tactics in a timely fashion. It is also better to seek approval for more outreach activities and materials and not use them than to seek piecemeal approvals as more activities are added.
- Clearly define development and execution roles between all project partners for outreach activities. Meet regularly to review outreach activities with the appropriate staff from the partners, including community engagement, outreach, member relations and professionals who interact with the target population.
- Engaging community partners is important to reach the target population but consider incentivizing referrals to get community partners to incorporate outreach activities for the study into their existing work as many are under-resourced. Streamline the customer journey from reaching out with interest about the study to signing the informed consent document. The more steps between expressing interest to becoming a participant increases opportunities for drop-off.
- Use focus groups of the target population to test messaging. It is important to understand the barriers and motivations to participation in order to craft effective messaging. It is also important to question assumptions like thinking people need something more than they think they do, i.e. not all pregnant individuals on Medicaid considered themselves to have trouble with transportation, especially when they have been able to facilitate their own rides by family or friends.
- Leverage captive audiences whenever possible. To protect the integrity of the study, the MCOs were limited in their ability to assist in outreach. As the MCOs already had established direct lines of communications to their members, given different circumstances, working through the MCOs to call and speak to their members directly about the study could be an effective outreach strategy.
- Recruiting a very targeted population from a limited candidate pool requires extensive communication, outreach and engagement. Allocate a healthy budget and staff to account for the breadth and depth of activities necessary to recruit within this population.

10.2.5. Project Stakeholders

Each project was led by the City, with vendor support playing a critical role in implementation. Vendors were primarily responsible for planning, documentation, testing and integration, and delivery of system functionality. For PTA, these vendors and their roles are summarized in **Table 10-4**.

Table 49: Prenatal Trip Assistance Project Vendor Responsibilities

Vendor	Role/Responsibility
Kaizen Health	Ÿ **Mobile app development** Ÿ **Web portal development** Ÿ **Call center** Ÿ **Contract with mobility providers to execute trips**
HNTB	Ÿ Project management Ÿ Development of systems engineering Ÿ Cooperative Agreement deliverables
Michael Baker International	Testing support
Engage (MurphyEpson, PolicyWorks, Linden Liaisons)	Outreach and engagement
StepOne/Physician Care Connection	Recruiting and screening

Source: City of Columbus

While the project team worked throughout the Cooperative Agreement to develop, deliver, operate and maintain the PTA project, stakeholders played a critical role in the process. **Table 10-5** summarizes the specific stakeholders that were engaged, as there were many diverse groups that came together to make the project successful. This table serves to highlight their contributions by categorizing them into three areas to indicate when their participation was used:

- **Systems Engineering –** These organizations/groups contributed to defining end-user needs, ConOps or Request for Proposal documentation.
- **Development –** These organizations/groups contributed to the build out of the project. This includes study development, integration, and testing, as well as recruitment/outreach planning.
- **Demonstration –** These organizations/groups contributed to the operations and maintenance of a project from go-live to end of the demonstration.

Table 50: Project Stakeholders

Stakeholder	Systems Engineering	Development	Demonstration
Government			
USDOT	X	X	X
Columbus Public Health	X		
Ohio Department of Medicaid	X		

Government			
Franklin County Department of Job and Family Services	X		
Researchers			
OSU Wexner Medical Center	X	X	X
Medical Providers			
OSU Wexner Medical Center	X		
OhioHealth	X		
PrimaryOne	X		
Mt. Carmel	X		
Heart of Ohio	X		
Lower Lights Christian Health Center	X		
Women, Infant, and Children Clinic			X
Community Organizations			
Moms2B	X		
CelebrateOne	X	X	X
Sidewalk Labs (focus group of pregnant individuals)	X		
Managed Care Organizations			
CareSource	X	X	X
Molina	X	X	X
Buckeye Health	X		
Paramount Advantage	X		
United Healthcare	X		

Source: City of Columbus

10.2.6. Project Costs

Table 10-6 and the figures below show the actual project costs, broken out by deployment and operations, and also illustrating the costs by vendor. Deployment covers the time from project start to the beginning of participant recruitment, May 31, 2019. Operations begins at recruitment and continues through the end of the project. There were no additional trip costs for the usual care group. For the intervention group, the per trip cost was fully or partially absorbed by the MCO. As explained in the next section, these figures do not cover the cost of providing the trip (driver and vehicle), as these costs are part of the MCO's normal responsibility to its clients.

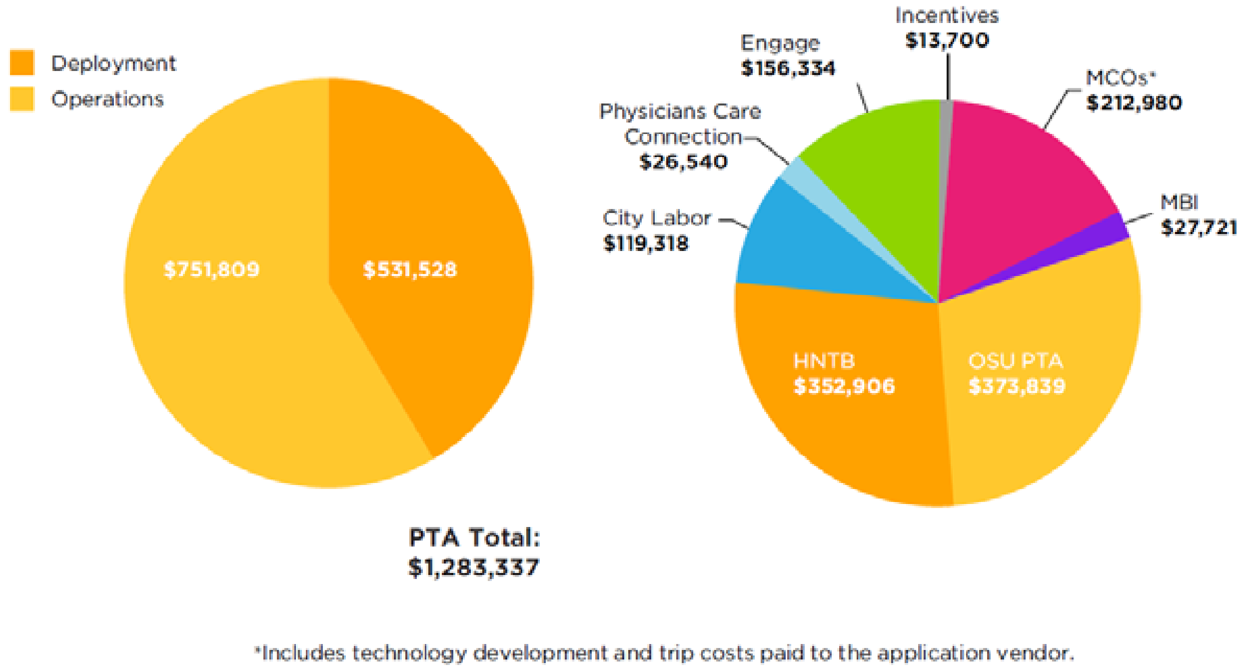


Table 51: Deployment and Operations Costs for the Prenatal Trip Assistance Project

PTA Vendor Actuals	Deployment	Operations	Total
Incentives	**$1,000**	**$12,700**	**$13,700**
MCOs (includes Kaizen Health reimbursement for technology development and trip reimbursement)	$15,625	$197,355	$212,980
MBI	$13,565	$14,156	$27,721
OSU PTA	$40,023	$333,816	$373,839
HNTB	$232,318	$120,587	$352,906
City Labor	$73,434	$45,884	$119,318
Physicians Care Connection	-	$26,540	$26,540
Engage	$155,563	$771	$156,334
Total	**$531,528**	**$751,809**	**$1,283,337**

Source: City of Columbus

10.2.6.1. OPERATIONAL COSTS

Given PTA is a time-limited project and will not be sustained in its current structure post-demonstration, this section outlines operational costs during the project. The operational costs listed in **Table 10-7** do not show a set number for fee per trip or an estimated number of trips as both vary greatly depending on health needs and distance of trip.

Table 52: Prenatal Trip Assistance Costs During Pilot Period

Description	Quantity	Cost	Recurrence
Kaizen Health Rides4Baby app and web portal development **Call center setup** **Technology integrations** **Training costs**	**1**	**$31,250**	**One-time fee**
Support options Continued maintenance Support inquiries Data reporting analytics	-	-	No cost during pilot period
Kaizen Health Licensing Fee	1	$11,000	Monthly

Source: Kaizen Health

For operational costs as they pertain to the MCOs' contracted NEMT providers, the contracts are not public record and given the highly competitive nature of the transportation brokers and MCOs to provide these services to their members, these numbers were not shared. Both CareSource and Molina have contracted with a transportation broker to provide oversight of each of their NEMT programs. This includes maintaining contracts with mobility providers to provide the direct service to the members, operating a call center to take requests from members, and assigning those approved trips to a mobility provider. For these services, the transportation broker is paid a monthly amount for each member. This is called a capitated payment model wherein a flat amount is applied at a per member rate for each member per month. For example, if the per member rate is $100 and there are 50 members, the monthly fee would be $5,000. The transportation broker would be responsible for providing all trips for that amount. Any amount unused for trips would be profit for the transportation broker, however, any amount spent over $5,000 would be a deficit to the transportation broker. This system allows the MCOs to have a known contractual amount and leaves the profit and loss risk on the transportation broker.

While an analysis of capitated rates cannot be discussed, the project was able to look at per trip costs and show that for Kaizen Health, the average price was $17.17 per trip. During the Request for Proposal (RFP) stage, Kaizen Health estimated the average cost would be $20.50.

10.2.6.2. PROJECT BENEFITS AND COST SAVINGS

The project benefits are many, including increased satisfaction from pregnant individuals who can book on-demand NEMT trips instead of needing to book trips in advance, the ease and freedom of using a smartphone app, website or call center to book a trip, and the safety and security of having driver information before getting into the car. The ultimate benefit from the project is showing that easier access to NEMT and better service through on-demand trips leads to more pregnant individuals attending prenatal medical appointments to ensure the health of themselves and their baby.

Cost savings shown by PTA come in the form of less than expected use of the call center and reduced costs for transportation services. While a call center did exist for the test group, it was seldom used given that the participants had the ability to request a trip through an app or website. PTA participants who had access to Kaizen Health's technology solution received additional transportation information in the form of real-time location services and driver information and the trips came at a lower cost than the traditional transportation broker. The PTA project has shown that lower costs can be achieved by using more on-demand services and by having the MCOs pay per trip and not at a capitated rate. A 2018 study performed by Pantonium[111] estimated the average NEMT trip cost was $27.

10.3. PROJECT EVOLUTION

10.3.1. Scope Changes

10.3.1.1. SMARTPHONE-ONLY SOLUTION

Originally, the technology solution for PTA was envisioned to be a mobile app that put scheduling pregnant individuals' next rides in the palm of their hands 24/7. While OSUWMC's initial research in Franklin County suggested that most pregnant individuals had cellphones (and indeed, most pregnant individuals in the Rides4Baby study did as well), the City scoped the PTA project to ensure that the system would benefit all pilot participants regardless of smartphone availability by having a web portal and a call center available to them. **Figure 10-10** showcases both the Rides4Baby mobile app and the website.

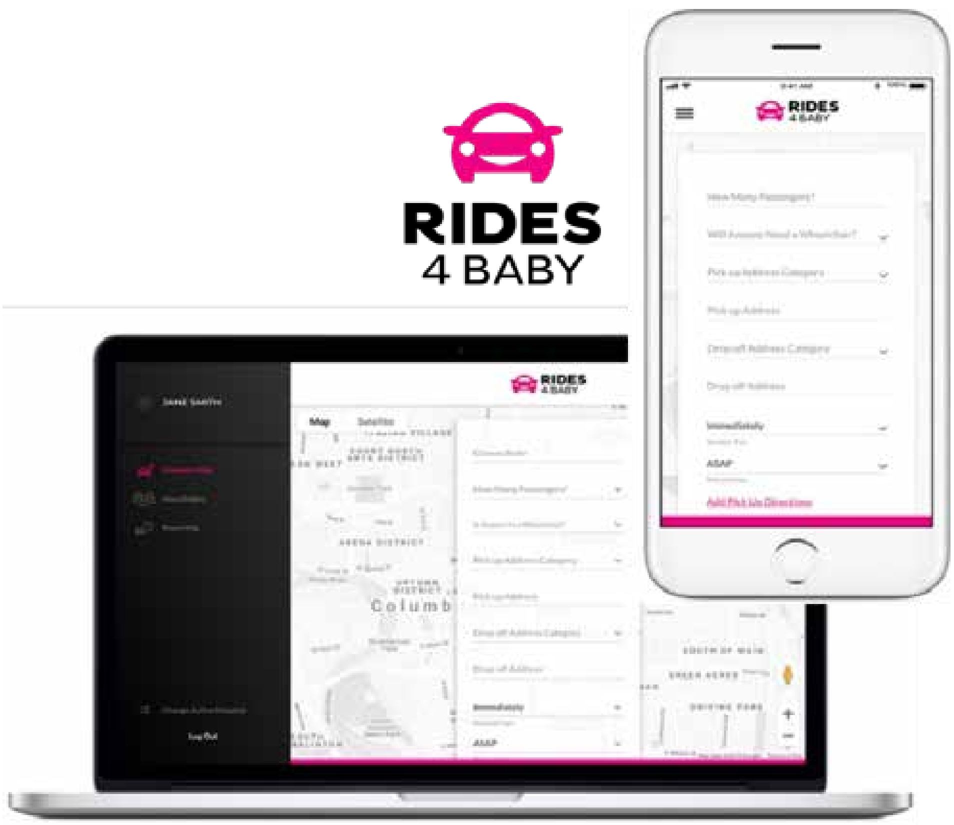


Figure 10-10: Rides4Baby Website and Mobile Applications

Source: City of Columbus

[111] https://pantonium.com/nemt-news-in-2018/

10.3.1.2. TIMELINE EXPANSION

Initially, the project team had envisioned the project as a piece of the City's portfolio to reduce infant mortality that would solely focus on the time period of pregnancy. While all stakeholders hoped that this project would contribute to the City's efforts to reduce infant mortality, OSUWMC's subject matter experts stressed that the study would not have adequate statistical power to examine this outcome. That said, with the OSUWMC's input as well as the input of CelebrateOne, the decision was made to continue to follow participants through pregnancy until eight weeks postpartum. This important time, commonly referred to as the 4^{th} trimester of pregnancy, is a period during which it is essential to ensure that postpartum individuals maintain access to maternal (i.e., postpartum follow-up) and infant (e.g., well child checks) health care services to provide additional opportunities for wellness screenings and parent education. Particularly important is education regarding proper sleep environments for infants, in an effort to reduce infant mortality due to sleep-related death.

10.3.1.3. GEOGRAPHIC SCOPE EXPANSION

During the ConOps phase, the project's geographic scope grew from the original concept of focusing on one neighborhood, Linden, to all eight CelebrateOne neighborhoods with high rates of infant mortality. A few months after project launch, it became clear that the enrollment goals would not be met and an expansion to the study area needed to be considered. An expansion could take place because infant deaths in Franklin County were not limited to the eight CelebrateOne neighborhoods. Therefore, the study team made the decision to expand the study eligibility criteria to all pregnant individuals with a residence in Franklin County. Despite this change, over 75% of the pregnant individuals who enrolled in the Rides4Baby study resided in one of the eight CelebrateOne zip codes.

10.3.1.4. MEDICAL OFFICES AS PROJECT PARTNERS

During stakeholder discussions, the medical offices with whom the project staff interacted indicated that missed or late appointments for pregnant individuals using NEMT negatively affected their business operations. Therefore, the project team started building a concept that would actively interact with medical office staff. However, after initial discussions regarding the possibility of adding medical offices to the transportation feedback loop (i.e., letting them know a patient was on the way), office staff indicated that they did not have the bandwidth to act on that information. Therefore, medical offices were not included in the final transportation intervention.

10.3.1.5. TRIP OPTIMIZATION

Initially, trip optimization to find the most efficient trip route was to be offered by Kaizen Health. Through the RFP process and contract negotiations, Kaizen Health stated that they could offer this solution to each NEMT Mobility Provider but historically, the NEMT Mobility Provider wanted drivers to use the NEMT Mobility Provider's trip optimization. Therefore, a system-wide solution was not needed or incorporated into the final transportation intervention.

10.3.1.6. LANGUAGES

Given that Columbus is a diverse community with residents speaking many languages, the project team initially planned to offer the transportation intervention in multiple languages. However, as the OSUWMC researchers prepared the IRB paperwork, it became clear that a multilingual approach would require additional time and money to translate and back translate (for confirmation) the informed consent documents and all study materials. Therefore, the study team determined that this was beyond the scope of what could be done in the short project timeline. Therefore, enrollment was limited to those who could read and understand English.

10.3.1.7. RIDE MODIFICATIONS

Originally, the PTA System was to be developed to offer an option to modify an existing ride reservation. However, after consulting with Kaizen Health, it was recommended against adding this feature. The Rides4Baby mobile app and web portal ride reservation screen displayed all upcoming rides. The concern was that adding the ride modification feature would be confusing for the traveler and result in user errors, such as individuals accidentally changing the wrong upcoming ride. Travelers were instead advised to cancel the trip and schedule a new one to replace it.

10.3.1.8. LIMITING RIDES TO MEDICAL OFFICES

Since NEMT had been defined as provision of transportation to medical offices and a narrow set of support services, PTA initially only included trips to those defined locations. OSUWMC researchers and CelebrateOne staff stressed that food insecurity was prevalent among the pregnant individuals that were targeted to enroll in the demonstration project. Therefore, in an effort to examine the utility of provision of this additional pregnancy support service in increasing pregnant individuals' satisfaction and decreasing adverse pregnancy outcomes, trips to grocery stores and food banks were included. This enhancement was used and appreciated by participants randomly assigned to the intervention group, with 10% of rides being trips to the grocery store or food bank.

10.3.1.9. INCREASING CHILD SAFETY WITH CAR SEATS

Once the project team expanded the study period to provide trips through eight weeks postpartum, the issue of car seats came up. The project team discussed whether pregnant individuals who needed NEMT, assumedly because they do not own a car, would own a car seat. Ohio law does not require the use of car seats in taxis or on busses. The OSUWMC researchers heard this was an issue and a review of the 2018 Sidewalk Labs report showed frustration that NEMT providers did not have car seats available for use. To ensure the safety of any child travelers, the project team worked with Kaizen Health to identify a transportation provider who would be willing to provide car seats for trips.

10.3.2. Cost and Schedule Changes

The PTA project had minimal changes affecting cost and schedule.

10.3.2.1. COST CHANGES

The PTA project cost less to complete than projected based on the following factors:

- As mentioned previously, despite the fact that the study team screened 4,120 pregnant individuals for inclusion in the demonstration project, only 143 met the eligibility criteria and enrolled. The original enrollment goal was 500 participants. Most of the pregnant individuals who were ineligible for participation were ineligible due to not expressing a need for help with transportation. Researchers believe that this is likely due to the way that pregnant individuals conceptualize the need for help, as many without a personal vehicle obtain rides from family, partners, or friends.
- As a result of COVID-19, in March-May of 2020, many local health care providers were only holding in-person visits with individuals who were sick. For many prenatal care providers, non-emergency visits were conducted via telemedicine obviating the need to take an NEMT trip. Further, even when health care offices re-opened for in-person visits, they were not permitting partners or other family members to attend, which led some to delay care. Finally, given the numerous public health messages to stay at home in the early months of the pandemic, it is likely that pregnant individuals delayed well visits due to safety concerns.

- Participants took fewer trips than projected. Only 66% of pregnant individuals in the usual care group took an NEMT trip during the study period, with those travelers taking a median of only two trips. In the intervention group, 87% of participants took at least one trip during the study period with the median number of trips being 19.
- While the budget initially planned to reimburse the MCOs for staff participation in the project, the MCOs kindly agreed to contribute staff effort in-kind to the project. This was impactful as there was a substantial amount of MCO staff effort for this project, including regular project meetings, RFP assistance, contract negotiations, data collection and de-identification, and work with the OSU researchers and Kaizen Health.

10.3.2.2. SCHEDULE CHANGES

As it became apparent that enrollment was lagging behind what was expected, OSUWMC researchers suggested lengthening the recruitment window by limiting late 2020 enrollment to pregnant individuals who were further along in their pregnancy and would therefore deliver by the February 2021 deadline. As such, the end date of enrollment was extended from June 30, 2020 to November 15, 2020. This was ideal to balance out earlier enrollments. In the early part of the project, OSUWMC researchers had enrolled more pregnant individuals who were earlier in gestational age that they had initially anticipated.

10.3.3. Changes to Stakeholders and Partners

During concept development, the more the project team learned about the NEMT system, the more expected project partners evolved.

10.3.3.1. OHIO DEPARTMENT OF MEDICAID

The Ohio Department of Medicaid (ODM) administers the state's Medicaid program. In the concept phases, the project team believed ODM would be the portal through which to run the project. While ODM is responsible for executing Medicaid coverage for Ohioans they do not provide direct services to Medicaid recipients. Rather, NEMT is provided through state contracts with MCOs and the Department of Job and Family Services (DJFS) in each of Ohio's 88 counties. The vast majority of pregnant individuals receiving Medicaid participate in an MCO, making the MCOs the main provider of NEMT.

As engagement with ODM increased, the study team learned that ODM was in the process of reviewing the NEMT services provided to Medicaid recipients. The ODM review was statewide and focused on all recipients of NEMT, not just prenatal members. The project team attended ODM's NEMT public meetings to hear the public's concerns, but unfortunately, much of the conversation focused on service and delivery in rural areas rather than the urban areas within which PTA was focused.

In the end, while ODM provided valuable information for and was supportive of the PTA project, ODM did not actively participate as a demonstration project partner.

10.3.3.2. FRANKLIN COUNTY DEPARTMENT OF JOB AND FAMILY SERVICES

Franklin County DJFS administers NEMT for select Franklin County residents, including individuals who participate in a Medicaid MCO and have exhausted their trip allowance as well as those who have a Medicaid Fee for Service Plan. Upon meeting with Franklin County DJFS, the project team learned that the NEMT services they provide are extremely limited accounting for a total of only 120 rides in 2017. These rides included all eligible Medicaid recipients and not just pregnant individuals. Therefore, the team decided that the effort and cost to integrate the Franklin County DJFS as a partner was not justified.

10.3.3.3. MANAGED CARE ORGANIZATIONS

As the ODM contracts with MCOs to provide Medicaid services to qualifying Ohio residents, the project team contacted the five MCOs early in the PTA concept development to invite them to partner on the demonstration project; however, after learning more about the services the MCOs provide and their respective market shares in Franklin County, the project team partnered only with the two largest MCOs: CareSource and Molina. Despite being competitors, the other three MCOs supported the demonstration project and have been willing to share information and data as requested by the project team.

10.3.4. Challenges

The PTA project encountered the following challenges:

- **The project's enrollment goals were not met.** Specifically, 143 pregnant individuals were enrolled which represents 29% of the 500-participant enrollment goal. While enrollment dropped off as the state's stay at home orders were enacted due to COVID-19, enrollment lagged behind the target since the project began. The researchers believe that this is due to fewer pregnant individuals than expected identifying as needing assistance with NEMT.
- **The COVID-19 pandemic presented several challenges to this demonstration project, most of which the project team successfully navigated.** First, when the stay-at-home orders were issued, all study staff were required to begin to work from home and all research study interactions were ordered to stop. OSUWMC researchers were quick to reach out to the OSU Biomedical IRB to request a waiver to continue the study under modified study procedures. As soon as this request was approved, all participant interactions moved from in-person to telephone interactions. Further, while the OSUWMC researchers could no longer deliver study gift cards or diapers in person, they were successful in mailing gift cards and delivering diapers via mail or in-person when COVID-19 prevalence decreased. The only COVID-19-related issue that the project was unable to overcome was the leveling off of enrollment.
- **The COVID-19 pandemic introduced challenges in food security to many people, including MCO Medicaid members. ODM recognized these issues and recommended the MCOs include trips to the grocery store and food banks as an allowed trip during these difficult times.** The MCOs acknowledged the recommendation and began providing trips to food resources for MCO members, including the usual care study group. This has created a positive change in value added benefits as Molina has permanently added these trips and CareSource has extended food trips through Q3 2021 and will reassess at that time. These positive changes for the usual care group created a confounding factor that the OSUWMC researchers had to include in the evaluation. **Table 10-8** lists the MCO changes to NEMT during the study.

Table 53: Managed Care Organizations' Updates to Non-emergency Medical Transportation

CareSource	Molina
Provided trips to food resources during the pandemic (currently providing trips through the third quarter of FY 2021)	**During the pandemic, provided trips to food resources, which is now a permanent value-added benefit**
Provided standalone trips to pharmacy during the pandemic	Provided standalone trips to pharmacy during the pandemic

Source: City of Columbus

10.4. CONCLUSIONS, LESSONS LEARNED AND RECOMMENDATIONS

The PTA project focused on one of the factors that can impact preterm birth, transportation. The PTA project aimed to enhance mobility and increase opportunity, efficiency and customer satisfaction for pregnant individuals who use NEMT provided through Medicaid benefits. PTA provided sources of high-quality data for ODM, MCOs, and others involved in tracking the prenatal care of Columbus Medicaid recipients.

Many NEMT services exist, but the lack of patient-centered technology and service has created gaps for certain pregnant individuals. The PTA project provided the following improvements to fill these gaps for pregnant individuals:

- Reliable transportation to and from medical appointments
- Access to on-demand transportation
- Knowledge of real-time driver location and arrival time
- Enhanced capabilities for patients to schedule NEMT trips
- Increased communications between NEMT mobility provider and patient
- Expanded types of places travelers could go, including grocery stores or food banks (not initially available to the usual care group, but added later)

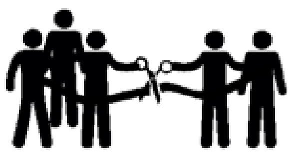
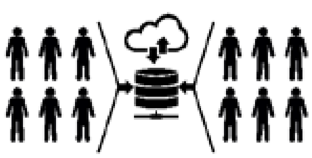
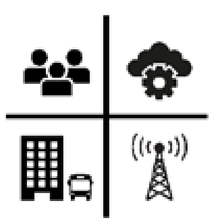
Prior to the deployment of the PTA project, NEMT was provided by all Medicaid MCOs. Members could not book online or via a mobile device and were required to contact a call center to schedule NEMT. Except under unusual circumstances, NEMT trips were required to be booked a minimum of 48 hours in advance, and covered members had a limit of 30 one-way trips covered per calendar year. Focus group data suggested that pregnant individuals were frustrated regarding the call center (hold times were long) and the need to schedule rides far in advance. Participants also expressed concerns regarding the timeliness of the drivers as well as the need to share, on occasion, rides with other members whom they did not know.

The PTA project aimed to address these issues by providing the intervention group with access to on-demand transportation via a smartphone app, web portal and call center. After comparing the two groups and examining the adequacy of prenatal care that participants received using the APNCU index, there were no notable differences in prenatal care utilization. Regarding preterm delivery, no meaningful difference in preterm delivery between the usual care and intervention groups was observed. The PTA project demonstrated that use of EST is feasible and well-received among pregnant individuals receiving Medicaid. Provision of EST resulted in increased use of NEMT benefits compared to usual transportation with supportive evidence of increased customer satisfaction. Overall, pregnant individuals assigned to the usual care group took fewer NEMT trips than pregnant individuals in the intervention group.

10.4.1. Smart City Vision

The PTA project addressed City challenges and met the original expectations defined in the Smart City Challenge. The project addressed transportation challenges by deploying a technology-based NEMT system that met the following U.S. Department of Transportation (USDOT) vision elements shown in **Table 10-9**.

Table 54: Prenatal Trip Assistance Project Relationship to USDOT Vision Elements

VISION ELEMENT #4 User-focused Mobility Services and Choices 	PTA provided a mobile app, web portal, and call center to schedule and track NEMT trips. PTA allowed for on-demand transportation services and included the ability to transport children by providing car seats.
VISION ELEMENT #7 Strategic Business Models and Partnering 	There are many public, private, nonprofit and educational institutions involved in improving birth outcomes and mitigating social determinants of maternal and child health. Enhanced transportation services through technological advances provided an opportunity to reshape business processes and models for the delivery of NEMT services. PTA partnered with OSUWMC as researchers, with local medical offices to define user needs and for recruiting assistance, and with the MCOs to deliver new technology to meet the needs of pregnant individuals.
VISION ELEMENT #9 Connected, Involved Citizens 	The PTA project had very targeted strategies for outreach to ensure the right individuals were reached to participate in the forward-thinking transportation software solution being tested. The recruitment campaign on improved mobility for pregnant individuals aligned the focus of this project with a city and statewide conversation on the effects of transportation on health.
VISION ELEMENT #10 Architecture and Standards 	The PTA project abided by the current architecture, standards and tools of the industry by using Architecture Reference for Cooperative and Intelligent Transportation (ARC-IT), Systems Engineering Tool for Information Technology (SET-IT) and published Intelligent Transportation Systems (ITS) standards to document the project's capabilities in the Smart Columbus System Architecture and Standards Plan (SASP). In this way, the PTA project is contributing back to the ITS community by creating a replicable architecture that can be reviewed/leveraged by other cities and that will make it more interoperable as other similar projects are deployed in the city, state and region.

Source: City of Columbus

10.4.2. Conclusions

CelebrateOne stated that “Infant mortality is not simply a health care issue. It is a complex, systemic problem influenced by a variety of factors and compounded by a range of social and economic conditions in disadvantaged neighborhoods.” This complex problem has been a major focus of the City of Columbus, Franklin County, and many community and business partners for more than eight years. The longevity of the focus on this problem and the many partners that have been working together allowed this project to take shape and be successful, even during a pandemic. The PTA project was successful in showing how a technologically advanced, customer-driven and on-demand system of NEMT can be used to better the lives of those in need of transportation. It also showed that in addition to increasing convenience for the pregnant individual, the PTA project improved efficiency and by using more on-demand trips, lowered the per trip cost based on national averages. Finally, the intervention group’s usage of the food trips infers that the need for transportation could extend beyond medical visits in the most vulnerable populations.

While this work is an important first step in examining the feasibility and utility of providing enhanced smart NEMT, there are a number of pressing questions that remain to be addressed. Specifically, what is the best way to identify pregnant individuals with transportation needs to ensure that they are aware of available services? Would provision of enhanced smart NEMT be of value to near-poor pregnant individuals who are not covered by Medicaid? Could enhanced smart NEMT be adapted to serve the needs of pregnant individuals for whom English is not their primary language?

Throughout the project there were lessons learned and recommendations for those interested in conducting an NEMT pilot or in implementing a technologically advanced NEMT system.

10.4.2.1. IMPACT TO RESIDENTS

PTA’s main goal was to improve birth outcomes and help babies get to their first birthday as shown in **Figure 10-11**. More convenient access to NEMT may seem like an indirect way to achieve this impact but the lack of convenient and on-demand transportation offered through NEMT can affect more than just someone’s arrival time. PTA’s solution of on-demand trip scheduling through a mobile app or web portal put the power of transportation into the hand of the pregnant individual. Being able to book a ride when it was needed allowed the pregnant individuals to plan their day better due to more predictable travel times. Pregnant individuals also did not have to carry heavy car seats with them to their appointment because PTA brought the option of using the NEMT provider’s car seats. All around, PTA offered a meaningful service to the residents that positively impacted the new parent and their child.

Figure 10-11: Baby’s First Birthday

Source: City of Columbus

10.4.3. Lessons Learned

The PTA project yielded valuable information regarding the utility and feasibility of employing an enhanced "smart" approach to deliver NEMT to pregnant individuals. While standalone interventions such as provision of enhanced "smart" NEMT are unlikely to meaningfully reduce adverse birth outcomes, including infant mortality, the preliminary work suggests that it may be a valuable contribution to providing pregnant individuals the wrap-around care that they need during the pregnancy and postpartum period. Even in communities with high rates of infant mortality, most individuals have a smartphone and are able to successfully navigate a mobile app to schedule a ride. Provision of on-demand transportation and more flexibility in terms of where they can go (e.g., the food bank or grocery store) increases pregnant individuals' satisfaction and makes them more likely to use available NEMT services.

A number of lessons were learned as part of the PTA project that would relate to conducting an NEMT study or for a government, medical office or MCO looking to implement technologically advanced NEMT. Lessons learned have been divided into two categories:

- **NEMT Implementation –** Lessons learned directed at entities that have the most oversight of NEMT activities and have the ability to direct or make changes that directly impact their members or patients.
- **NEMT Studies –** Lessons learned directed at researchers or anyone conducting a study that does not have direct access to implement NEMT as a service.

10.4.3.1. LESSONS LEARNED FOR IMPLEMENTING TECHNOLOGICALLY ADVANCED NEMT

- The private sector faces challenges when making changes. The MCOs' concerns about member care and the interest toward seeking ways to improve customer satisfaction were clear throughout the project. The interest in innovation was also apparent but MCOs are heavily regulated and cautious in implementing new services like on-demand trips. This can lead to slow adoption of new technologies and services.
- Validating MCO approved addresses quickly can be difficult for on-demand transportation, requiring building a database of allowable locations. MCOs provide trips for many different services and maintaining a complete list of allowable locations is difficult given new service locations are added throughout the year. Verification of locations and addresses was needed quickly for on-demand trip requests.
- There is more need beyond MCO prenatal members for this service. While the project team was identifying user needs and meeting with medical offices, it was clear that patients beyond those who were pregnant often complained about transportation being an issue for being late or missing appointments. Multiple times the project team was asked whether uninsured pregnant individuals could be part of the study. However, because the team was working with MCOs, the participants needed to be insured with one of the MCOs to participate.

10.4.3.2. LESSONS LEARNED FOR CONDUCTING AN NEMT STUDY

- **Recruiting**
  - While outreach was constant throughout project recruitment, using all possible sources from the beginning could have helped increase numbers. The communications plan for PTA used a layered, methodic approach to allow the message to be available in multiple formats one after the other, including social media, grassroots flyers, radio, etc. Using additional funds for recruiting to consistently use all communications mediums at the same time throughout recruitment may have increased enrollment numbers.
  - Community organizations like Moms2B and social workers are excellent resources to assist with understanding the needs and travel patterns of the study population. Gaining support and recruitment assistance from organizations that currently assist the target study population was invaluable. For example, a community partner, StepOne, informed the team that the number of pregnant individuals seeking assistance drops during the summertime and increases in the winter. This allowed for understanding when the summer enrollment was lower than expected.
  - On-site recruitment at OSU hospitals and clinics did not generate the number of participants that the study team expected. Many pregnant individuals were not able to stay after their medical appointment to complete enrollment activities. In addition, the pregnant individuals were able to travel to the doctor; therefore, transportation may not have been a significant need.
  - Often pregnant individuals indicated they did not have transportation challenges; as such, fewer pregnant individuals were eligible for participation in the project than was expected. This is contrary to what the project team heard from stakeholders. Pregnant individuals indicated that they rely on transportation from family, friends, and neighbors and do not use NEMT despite its availability.
- **Obstacles exist with data**
  - Transportation data are not collected in a standard format across MCOs or their transportation brokers, and unless ODM requires that standardization, there is little incentive for the MCOs to make this change.
  - Gathering health data can be difficult. For PTA, each participant had to sign an IRB approved consent to take part in the study and to allow the study team to receive their transportation records. Each MCO required a Business Associate Agreement to share data from the participant. A HIPAA release also had to be signed by the participant for StepOne, which was conducting the initial health screening to share that data with the study team.
- **Testing is required prior to deployment**
  - Documentation is critical throughout testing. Developing clear instructions and repeatable procedures for other users is key to success. Providing screenshots, writing down every step, etc. ensures information can be accurately relayed to developers to clearly identify needed changes.
  - Having diverse testers from all age groups, backgrounds and technology expertise benefitted this project.

10.4.4. Recommendations

Below are recommendations stemming from the PTA project that should be considered if adopting an enhanced “smart” NEMT program. Recommendations, like lessons learned, are broken into two categories:

- **MCO and Departments of Medicaid recommendations –** MCOs and departments of Medicaid are responsible for the implementation of NEMT activities and therefore, most of the recommendations fall into this category.
- **NEMT pilots or study recommendations –** While the PTA project is unique in that most cities will not have the resources to conduct or justify administering a pilot over a service that they do not operate; it is possible that another study in this area could be funded. This category focuses on recommendations for study teams researching transportation and health.

10.4.4.1. RECOMMENDATIONS FOR MANAGED CARE ORGANIZATIONS AND STATE DEPARTMENTS OF MEDICAID

- **Select an innovative transportation broker –** The PTA project was fortunate to contract with Kaizen Health. Not only was it innovative in approaching transportation and could provide guidance based on experience, it also had a passion for the work and this project.
- **Consider offering on-demand trips and on-demand scheduling requests from a mobile app and a web portal**
  - Pregnant individuals highly ranked having access to on-demand trips that did not require a pickup window of two hours. The participants could see exactly when the driver would arrive to ensure they would be prepared to leave.
- When using on-demand transportation, clearly define business rules before seeking a vendor. Having a database of allowable trip locations where members can go, when, and how many times is important for success.
- Consider whether concurrently addressing food insecurity with NEMT is advisable for the target population. Food insecurity is a growing issue for some populations and the COVID-19 pandemic has exacerbated it.
- Medical offices were interested in the study and wanted to be helpful, but did not have available resources to track patients, even with a free system. Any technology being considered should take into account that staff will not be focused on interacting with the system all day and should consider how the technology could work into the medical office's existing scheduling system automatically.
- When implementing technology to automate services, considering the people aspect is still important. Even though PTA allowed on-demand trips to be scheduled completely through technology, having a call center support team available was necessary when issues arose. Call center availability is also necessary in case the mobile app has technical issues.

10.4.4.2. RECOMMENDATIONS FOR CONDUCTING A NON-EMERGENCY MEDICAL TRANSPORTATION STUDY

- **Maximizing partnerships/stakeholder relationships –** As with any project, partners can help make a project successful or they can hold you back. In PTA, the right partners came in many shapes and sizes. From an experienced and knowledgeable research team to forward-thinking and community-minded MCOs wanting to test transportation options for their members, and from a smaller technology company with a great product to community programs focused on reducing infant mortality, PTA had the right partners.
  - With all partners, the project team learned to engage early and often. Keeping the entire team engaged with all aspects of the project allowed for expert insight as the project team continued to learn about NEMT. It also allowed for a real sense of team when everyone knows the same information and knows they have a voice at the table.

  - Defining roles and responsibilities for all the team members was also important to ensure that everyone was bringing value to the project. The MCOs were integral members as the major implementer of this project but they also asked to be part of the testing team to verify the technology, and serve as subject matter experts throughout the project to help ensure the project's vision and goals were in line with what users needed.
- **Know the existing system –** For PTA, the team had to learn the NEMT system that serviced pregnant individuals on Medicaid, both public and private. This ensured that all gaps were truly identified from all users' perspectives before drafting a concept. Building on top of the user needs study from Sidewalk Labs, the project team met with all of Ohio's MCOs multiple times to ensure the team understood what transportation benefits were available to Medicaid members, what process a member had to go through to use them, and how the MCOs were contracted with a transportation broker to provide transportation. The team also met with countless medical facilities.
- **Recruiting**
  - While the project team knew recruiting would be challenging, recruitment was slower than expected. The main lesson learned was that all recruiting channels could have been used from the beginning. Originally, the team started recruiting through StepOne then supplemented its work with grassroots and social media marketing. After a few months of recruiting and participants were not signing up as fast as expected, the team brainstormed additional recruiting ideas which included the OSU research team interacting with pregnant individuals at medical clinics. Adding this additional recruiting method from the beginning would have been helpful to get the message in front of the pregnant individuals where they were going to be.
  - Another recommendation is to conduct the study screenings over the phone rather than in person. This came out of necessity due to COVID, but the pregnant individuals were very receptive to do it by phone rather than scheduling a meeting.
- **Testing –** All testing was conducted before recruiting occurred. While the test team attempted to run every scenario a participant might run, it became clear in the first month that having participants test the app would have been helpful. Most of the issues that came to light were small issues regarding the way a medical facility was listed in the mobile app or letting the project team know about a pop-up Lamaze class. The user-need research was exhaustive but once the solution was ready, sitting side-by-side with participants testing the app would have been beneficial.
- **Verify what you hear from stakeholders –** With a multitude of stakeholders in the NEMT industry, many with different goals, views, and experiences, it is critical to gather as much feedback as possible. Hold focus groups, conduct interviews and administer surveys for potential participants, users, and administrators of NEMT services. Stakeholders will have different views of what qualifies as transportation challenges. For example, the team heard from stakeholders that vehicles with car seats were a great need for the study population. However, based upon car seat usage data, it was not as highly needed as anticipated.

10.5. SUMMARY

The connection between transportation and health outcomes made the PTA project perfect for Columbus as it searched for more solutions to tackle the fight against infant mortality. PTA was successful because of the experienced and passionate team from the MCOs to the research team and the vendor. While the City does not operate NEMT, the MCOs' changes to NEMT during the pandemic show that this project gave the MCOs the information they need to think innovatively as new transportation broker contracts are negotiated. CelebrateOne and the City continue to advocate for additional programs focused on reducing infant mortality and improving birth outcomes. In late 2020, the State of Ohio created a task force to eliminate racial disparities in infant mortality. Data from the PTA project is expected to be helpful in developing solutions, as task force members include representatives from the City and from the MCOs which were part of the PTA project.

Chapter 11. Smart Mobility Hubs

11.1. PROJECT OVERVIEW

The Smart Mobility Hubs (SMH) project was designed to improve the availability of transportation options for people living in areas with limited connectivity. The Linden neighborhood was identified as the location for the project, as its residents face numerous socio-economic challenges, including low household income, lack of major employers, and high infant mortality rates.

These problems are compounded by the lack of access to transportation options, as there are numerous job centers throughout the Columbus region, including some a short drive from this neighborhood. Easton is a high-traffic retail destination and office center in the northeast part of Columbus, just a few miles from Linden. Although Easton is a major employment center, the jobs in this area have a high turnover rate. Research has shown that a major contributor to this type of job instability is the lack of reliable transportation, including first mile/last mile (FMLM) challenges related to safety and mobility.

Six SMHs shown in **Figure 11-1** were deployed to provide travelers with consolidated transportation amenities such as Interactive Kiosks (IKs) with Wi-Fi and Emergency Call Buttons (ECBs), enabling modal transfers between a variety of transportation options that exist in the City, and providing access to comprehensive trip-planning tools such as Pivot – the Multimodal Trip Planning Application (MMTPA). Taken together, these services were intended to facilitate multimodal trips, including coordinating FMLM connections.

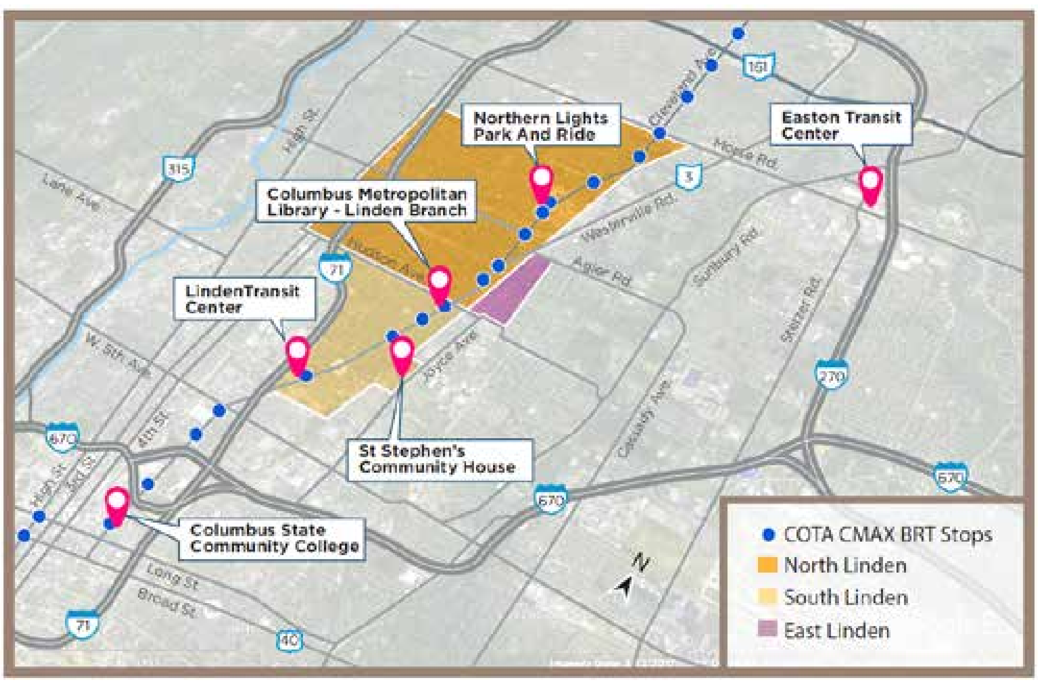


Figure 11-1: Smart Mobility Hub Locations

Source: Google Earth Pro, City of Columbus

11.2. DEPLOYMENT SUMMARY

11.2.1. Systems Engineering Approach

The City used a traditional systems engineering process for the development of the project to ensure that the original vision developed in the Smart City Challenge was vetted, refined, and modified as appropriate according to site stakeholder and community input. Systems engineering is described in more detail in **Chapter 2**.

As part of this process, the project team had to fully document and vet user needs and system requirements, and each aspect of the systems engineering "V-Model" (see **Figure 2-3** in **Chapter 2**) was addressed, with deliverables developed for each stage and posted to the Smart Columbus website.[112] The challenge to using the systems engineering process for the SMH project was that not only was the project team designing a system, but it was also designing physical, non-connected amenities. The development of the System Requirements and Specifications (SyRS) prior to the evaluation of available kiosk technologies ensured the system desired was delivered, and the project team was able to determine that the IKE Smart City product met the requirements prior to engaging in discussions with the vendor and partners to leverage an existing city deployment agreement.

The specific service gaps in the system that the SMH project intended to address include:

- Lack of physical facilities offering trip-planning, multimodal transit options, and other amenities at centralized locations
- Limited FMLM transportation options; these limitations make it difficult for transit-dependent residents to access basic services such as health care, grocery stores, and banking
- Inadequate optimization of ride-sharing trips
- Exclusion of unbanked users and users without smartphones from travel options
- Lack of adequate safety features like ECBs at transit facilities

Any changes recommended through this development process had to be vetted and managed appropriately. One example of this process change was the solicitation of bids to complete the physical installation of amenities. The City of Columbus received no bids on the construction contract due to the small amount of work and multiple sites involved, so City forces were tasked with completing the work for the concrete pads, signage, and pavement markings. This was a deviation from the original plan but did not impact project goals. The costs to install each site were minor and were easily completed by the skilled labor that the City employs. Also, by utilizing in-house forces, the hubs can be more easily scaled across the City.

Prior to launch, the system had to be tested and verified that it was delivered as designed. The test plan was developed based on the project system requirements that ensure traceability with the system delivered.

The verification process also included the assurance that agreements have been completed. While not part of the construction, the execution of agreements enabled the installation of the amenities, defined the roles and responsibilities for deployment, and enabled the mobility providers to enter onto private property to deploy assets. The phases and tests conducted were as follows:

- Preliminary testing – Individual, basic tests of each function that the system was required to perform
  - IK functionality
  - Trip planning with Pivot, the Smart Columbus MMTPA installed on each IK

[112] https://smart.columbus.gov/projects/smart-mobility-hubs

  - ECBs
  - Wi-Fi access
- Acceptance testing – covered the functional use of the entire system
  - Validated the Application Programming Interface (API) was active and providing the Smart Columbus Operating System (SCOS) with data

11.2.2. Project Launch

The initial launch for the SMH project was anticipated to occur in early April 2020. As some of the last remaining testing items were occurring, the COVID-19 pandemic hit Columbus and delayed the launch date. While all testing and installations were complete for the project, travel in the region was greatly reduced through Ohio's stay-at-home order.

As the project team monitored travel patterns in the region as well as pandemic conditions, a revised launch date was set for July 28, 2020. While travel in the region had not returned to pre-pandemic levels, there were indications that some travel had returned – especially for workers deemed essential or those that could not work from home – and the SMH project could provide some mobility benefits. Central Ohio Transportation Authority (COTA) was operating fare-free and with some reduced service until January 11, 2021, providing some financial relief for those hit economically by the pandemic.

The launch press conference was combined with two other Smart Columbus initiatives: the re-launch of the Linden Empowers All People (LEAP) automated shuttle as a food pantry service, and the start of the public recruitment for the Connected Vehicle Environment (CVE). Because all three projects had a large footprint in the Linden community, it made sense to combine the announcements into one. Given the recommendations to limit unnecessary gathering, the press conference was held virtually. Speakers included Mayor Andrew J. Ginther, Mandy K. Bishop (the City's Program Manager), and Sophia Mohr (COTA's Chief Innovation Officer) to speak about the SMH project. While the original launch plan included demonstration rides, helmet giveaways, kiosk training, and other mobility-focused activities, this plan needed to be scaled back and the information disseminated through a press release to local, national and trade media, and posted to the Smart Columbus website.

The launch was covered in local publications including the Columbus Dispatch and Columbus Underground. Additionally, the project launch was shared with local stakeholders through area commission meetings and community partners like St. Stephen's Community House, Community of Caring Development Foundation, and Active Linden. Ads were also placed on the six SMH kiosks through IKE Smart City, the IK vendor.

11.2.3. Demonstration

Once the SMH project launched, the project data were monitored. The project team had access to IKE Smart City kiosk data, ChargePoint electric vehicle charging data, and CoGo bike-share data in addition to trips booked using Pivot that originated, ended, or traveled through each SMH. While most of the data are summarized in the Performance Measures Results Report, a few key observations are included below.

With CoGo bike-share, there were not many trips between two different SMHs (inter-hub trips). A majority of the CoGo bike users who began their rental at an SMH returned the bicycle to that same SMH, potentially using it as a FMLM connection. Many trips also ended at a non-SMH location. The introduction of the electric pedal-assist bicycles was successful, and the option became a very popular choice, accounting for 26% of bike-share trips at the SMH since the launch. The CoGo bike trips by SMH location are presented in **Figure 11-2.**

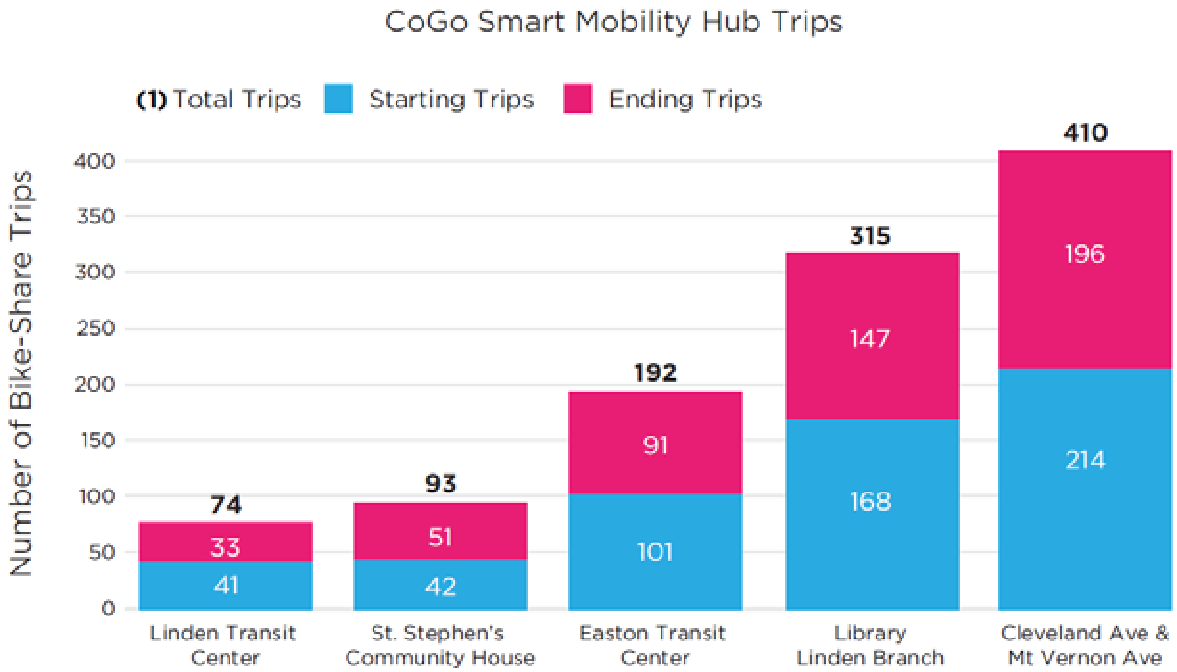


Figure 11-2: CoGo Bike-share Trips by SMH

Source: City of Columbus, https://discovery.smartcolumbusos.com/visualization/veeu0omf

Figure 11-3: A Traveler Interacts with the IKE

Source: City of Columbus

Figure 11-4 displays the IK interactions with visitors at each SMH site through March 31, 2021. An interaction with the IK is recorded when a new device carried by a traveler passes by the screen. Based on this data, the Linden Transit Center had the most foot traffic and St. Stephen's Community House had the least amount of traffic. Due to COVID-19, St. Stephen's had reduced programming, limited guests in the building, and was closed to visitors for some time. Additionally, with the kiosk being located inside the building, interactions with the IKs were drastically limited.

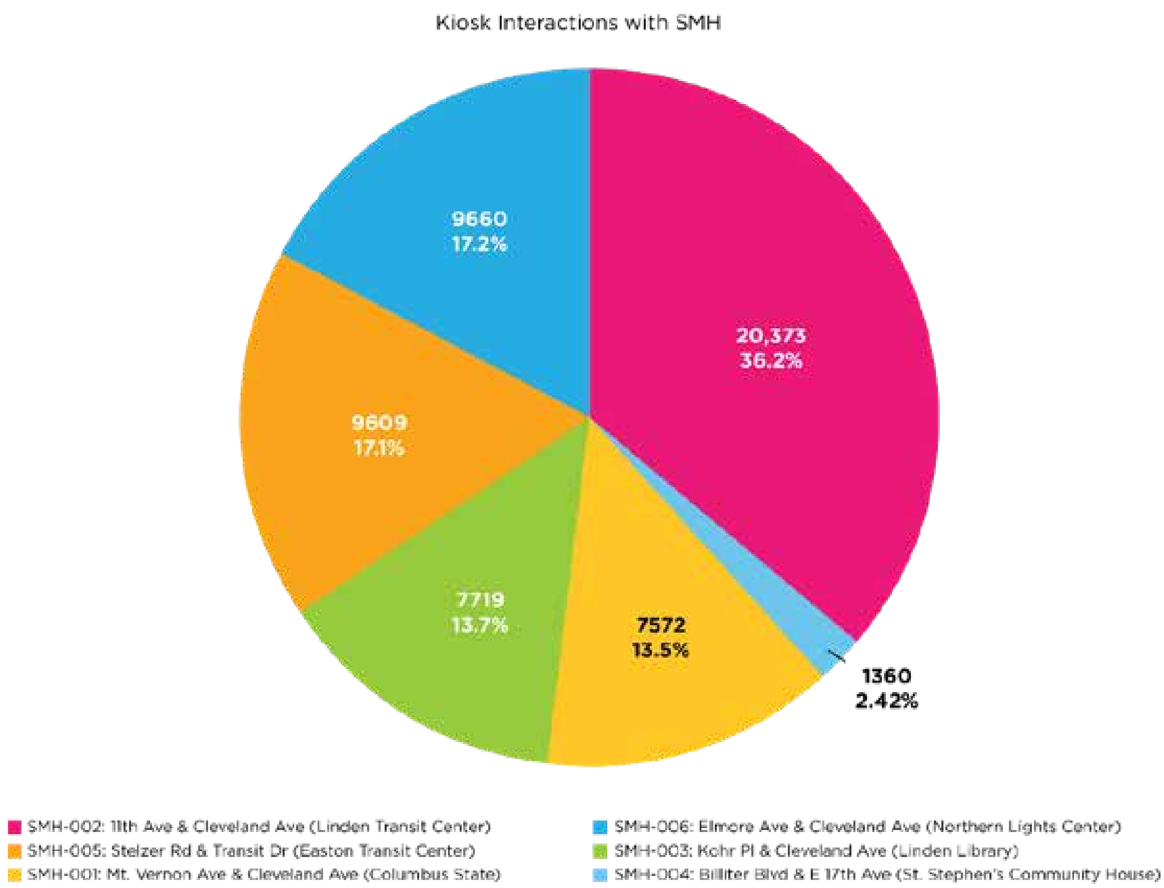


Figure 11-4: Kiosk Interactions with SMH Visitors

Source: City of Columbus, https://discovery.smartcolumbusos.com/visualization/rctetf54

Figure 11-5: Easton Transit Center SMH

Source: City of Columbus

Upon conclusion of the Smart Columbus Program, management of the SMH sites will be turned over to the private property owners, where applicable. The agreements with the site owners were developed with the sustainability of the sites in mind to ensure they outlived the demonstration project. The mobility provider agreements were also signed to continue beyond the program. It will be the responsibility of the mobility providers and site stakeholders to renew the agreements when they expire. The maintenance of the sites will transition from the City to the stakeholders, and the management of the signage and pavement markings will transition to those stakeholders.

11.2.4. Communications and Recruitment

The project publicly launched at the end of July after several months of delay due to the pandemic. Looking at multiple sources of data – traffic counts, bus ridership, kiosk interactions – it is evident that the travel volumes were significantly down compared with the time before the stay-at-home order.

In addition to reducing travel demand and use of SMH services, the reduced travel also lessened the project team's ability to build awareness. Factors that impacted the communications and outreach related to SMH included reduced bus ridership; statewide and city stay-at-home orders; public concerns about using shared mobility options; and the number of temperate weather months remaining during the demonstration period.

The key audiences were residents living or traveling within two miles of an SMH location.

Key messages included:

- SMHs bring the City's many transit options together at a single, convenient location so that you can get where you need to go, efficiently and affordably.
- SMHs are located largely along the CMAX line in the Linden area, making it easy to connect with transit and other modes of transportation to get to work, school and other destinations.
- Each SMH is equipped with an interactive kiosk known as “IKE” that provides access to Wi-Fi, Pivot, and listings of restaurants, shops, activities and social services.

- The City of Columbus has partnered with property owners throughout Linden to ensure that the SMH sites are maintained and will remain long-term community assets.
- The City of Columbus and its partners are taking significant measures to promote the health and safety of SMH users during these unprecedented times.
- Linden is leading the way in bringing smart technology and mobility into the City's neighborhoods, creating ladders of opportunity for residents, and serving as a model for neighborhoods in Central Ohio and beyond.

The key tactics to reach these audiences occurring July 30, 2020, through March 31, 2021, are listed below. These are divided into the types of media used – paid, earned, owned or shared, as **Chapter 3, Section 3.2.4** describes in detail.

11.2.4.1. PAID MEDIA

- Paid digital ads on Google, Facebook, Instagram, and Twitter
- Ads on six SMH IKE kiosks

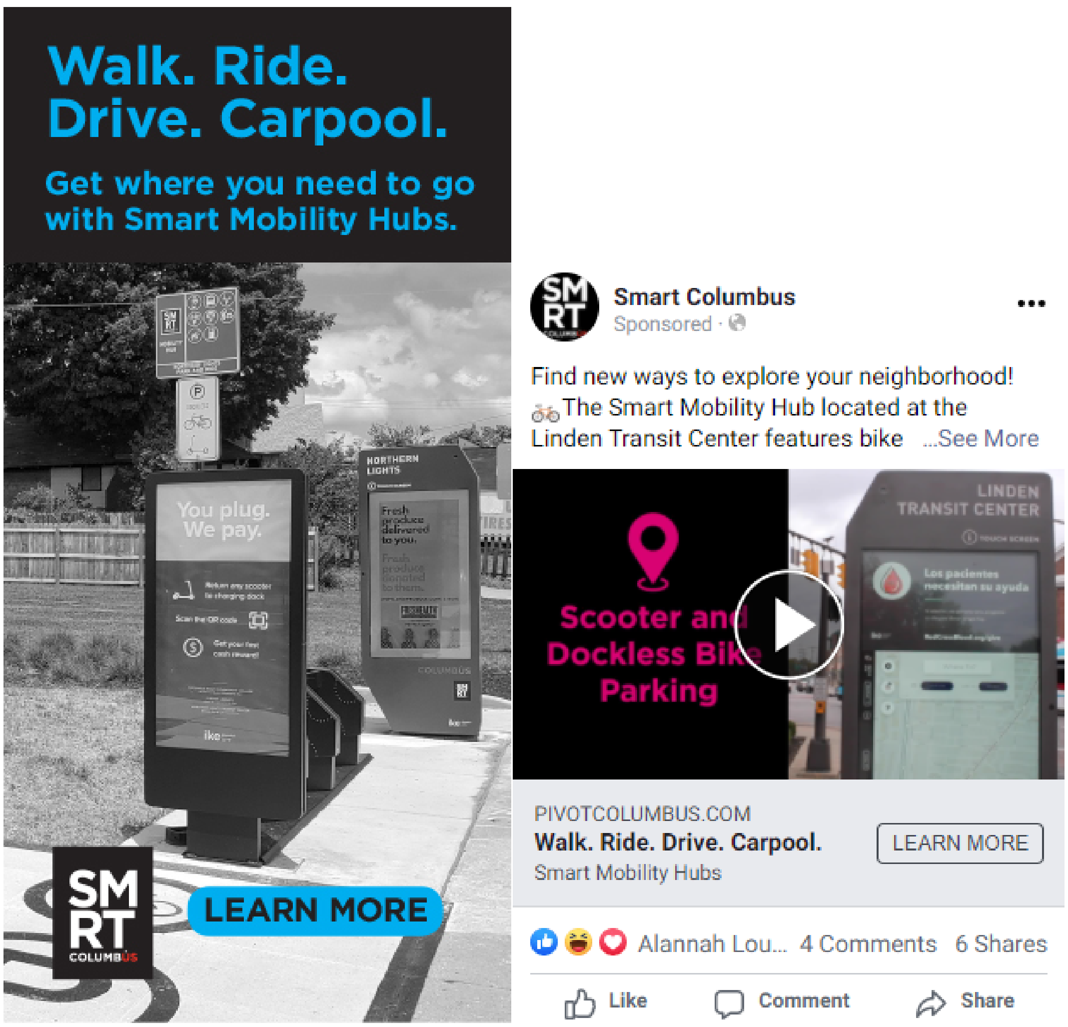


Figure 11-6: Examples of Paid Media

Source: City of Columbus

11.2.4.2. EARNED MEDIA

- Launch press conference and press release
  - Picked up by The Columbus Dispatch, Columbus Underground, and local television station

11.2.4.3. OWNED MEDIA

- Organic social media posts on Smart Columbus accounts
- Updates in Smart Columbus newsletter

11.2.4.4. SHARED MEDIA

- Stakeholder updates at area commission meetings or through community partners like St. Stephen's Community House, Columbus Metropolitan Library, Columbus State Community College, the Community of Caring Foundation, and neighborhood resident consultants known as "Linden Liaisons" utilizing a toolkit with one-page flyers, FAQ sheets, sample newsletters, social media copy and graphics, etc.
- Shared social media posts from location partners like the Columbus Metropolitan Library, St. Stephen's Community House, and Columbus State Community College
- Select community events like working with a local bike ride group to plan a ride with a stop at one of the SMH locations for short demonstration, and providing printed informational materials for inclusion in food pantry boxes at St. Stephen's Community House
- Website[113]
- Google Business Listings

[113] http://pivotcolumbus.com/smart-mobility-hubs

Figure 11-7: Active Linden Bike Ride

Source: City of Columbus

The paid digital campaign had two phases; one with a graphic and copy focus aimed at raising awareness about the new concept of SMH, and the second using videos to raise awareness about the locations and features available at each hub and to drive use of the services at the hubs.

Google Display was the best platform to help spread awareness, accruing over 2M impressions throughout both campaigns. Given the nature of the Google Display Network, click-through rate was relatively low, yet the frequency of ads and high reach contributed to keeping the SMHs in recent memory of the target audiences. In terms of engagement, Facebook performed the best not just in terms of driving website traffic, but also social interactions around the Smart Mobility Hubs. Together the campaigns drove over 16,000 post engagements, 2,000 clicks, 170 reactions, and 45 shares.

In terms of both awareness and engagement, Twitter performed at much lower rates compared to Facebook and Google and had higher costs per engaged user. Another downside of Twitter is the higher price elasticity to social events (Thanksgiving holiday, presidential election), which increased costs considerably. However, the addition of Twitter brought in the benefit of reaching a significantly different audience (predominantly male-identifying, under 39 years old) which balanced Facebook's over 35 years old, female-identifying audience and broadened the possibility for social interactions to everyone.

The communications team recommends featuring imagery of the services in photos or videos from the beginning of the campaign to increase engagement and communicate ideas faster than just through ad text. The team also recommends setting up Google Business Listings for each hub location before the project goes live, as the verification process can be lengthy. Creating Google Business Listings provides added exposure, credibility, and increased ease of use for the target audience, who is likely already familiar with using Google to find things. The ease of navigation through the listing and richness of information (e.g., service explanations, images, videos, updates) makes it an important tool. A challenge of setting up the Google Business Listing was that the City did not "own" the business being added, and sites do not have a traditional store front, so several forms of verification were needed to publish the listing including a video conference at each location.

Ultimately, reliance on paid and shared tactics was more than originally planned due to the lack of grassroots engagement activities because of COVID-19 restrictions. Providing content to partners to share on their owned communication channels was the best-performing grassroots engagement tactic. The communication team recommends meeting with each organization to understand its unique communication needs and developing content unique for each entity, rather than developing a universal toolkit that can be shared broadly. The more customized approach helps with buy-in and aids in the content being shared more than once and in multiple ways.

When the MMTPA (Pivot) was launched in December 2020, SMH messaging was incorporated and cross promoted in the neighborhood-focused digital campaign through March 31, 2021.

11.2.5. Project Costs

Table 11-1 and the pie charts below show the cost of deploying and operating the SMH project along with the specific vendors of the project. Deployment covers the project beginning until launch on July 28, 2020. Operations covers the launch until the end of the demonstration. Of the shown deployment costs, $271,178 was expended on construction and installation.

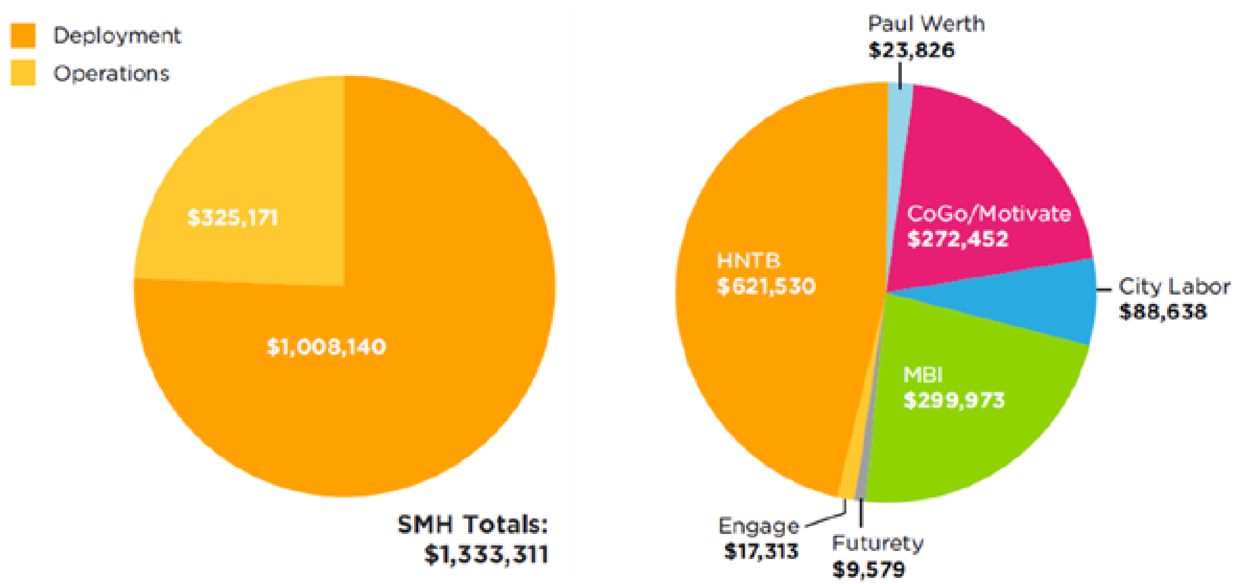


Table 55: Deployment and Operations Costs for the Smart Mobility Hubs Project

SMH Vendor Actuals	Deployment	Operations	Total
CoGo/Motivate	$197,452	$75,000	$272,452
City Labor	$73,726	$14,910	$88,638
MBI	$217,598	$82,375	$299,973
Engage	$9,885	$7,428	$17,313
Futurety	-	$9,579	$9,579
HNTB	$499,009	$122,521	$621,530
Paul Werth	$10,469	$13,357	$23,827
Total	**$1,008,140**	**$325,171**	**$1,333,311**

Source: City of Columbus

Table 11-2 provides the contributions of key leveraged partners that are not included in the project costs listed in **Table 11-1**.

Table 56: SMH Key Leveraged Partners Contributions (in Dollars)

Partner	Amount	Item
IKE Smart City	Not disclosed	Six IKs
AEP (through COTA)	Not disclosed	Three ChargePoint Level 2 Charging Stations

Source: City of Columbus

Table 11-3 provides recurring O&M costs by project, and the party responsible for the cost after the demonstration period.

Table 57: Operations and Maintenance Costs and Funding Sources

Maintenance of SMH Amenity	Responsible Party	Cost to Responsible Party	Comments
IK including ECB and Wi-Fi	IKE Smart City	Not available	Ÿ Per vendor, cost information is considered confidential Ÿ End-of-life replacement expected at ten years. Multiple components of IK will be replaced as needed over the years. Additional IK components include: Monitors replaced at five years Computers replaced at five years Modem replaced at five years Air conditioners at four and eight years, or twice in the ten-year lifespan Security network video recorder at five years or once in the ten-year lifespan Emergency call assembly at five years or once in the ten-year lifespan
CoGo Infrastructure	CoGo	Not available	Per vendor, cost information is considered confidential
Pavement markings and signage maintenance costs at SMH sites (costs below include replacement of all signage and pavement markings)			Signage and pavement markings installed will be inspected and replaced as necessary or when damaged
Columbus State Community College	City of Columbus	$2,700	Estimated cost every seven years
Linden Transit Center	COTA	$3,200	Estimated cost every seven years
St. Stephen's Community House	St. Stephen's Community House	$3,900	Estimated cost every seven years

Metro Library – Linden Branch	Columbus Metropolitan Library	$3,550	Estimated cost every seven years
Northern Lights Park and Ride	COTA	$3,450	Estimated cost every seven years
Easton Transit Center	COTA	$1,700	Estimated cost every seven years

Source: City of Columbus

11.2.6. Project Stakeholders

Each project was led by the City, with vendor support playing a critical role in implementation. Vendors were primarily responsible for planning, documentation, testing and integration, and delivery of system functionality. For SMH, these vendors and their roles are summarized in **Table 9-6**.

Table 58. Smart Mobility Hubs Project Vendor Responsibilities

Vendor	Role/Responsibility
IKE Smart City*	Kiosk supplier
City of Columbus Department of Public Service*	Infrastructure installation/construction
MTECH / Etch	Pivot developer
Michael Baker International	Project Manager
HNTB	Systems engineering documentation, Cooperative Agreement deliverables, development of installation/construction plans, testing
CoGo/Motivate/Lyft	Bike-share stations
Engage *(Community of Caring Foundation, Linden Liaisons)*	Outreach and community engagement
Futurety	Recruiting and adoption (Strategy/Planning, Digital Analysis and Audience Segmentation, Paid Digital Management/Optimization, Website Development, Tool Integration/Automation, Database Development & Visualization, Analytics)
Paul Werth	Recruiting and adoption (Strategy/Planning, Messaging, Copywriting, Graphic Design, Video Capture and Editing, Grassroots Engagement, Crisis Communications)
Fahlgren Mortine	Recruiting and adoption (Website and survey development)

**Services/responsibilities were not procured but provided through key leveraged partners or the City forces.*

Source: City of Columbus

While the project team worked throughout the Cooperative Agreement to develop, deliver, operate, and maintain the SMH project, stakeholders played a critical role in the process. **Table 7-11** summarizes the specific stakeholders that were engaged, as there were many diverse groups that came together to make the project successful. This table serves to highlight their contributions by categorizing them into three areas to indicate when their participation was used:

- **Systems Engineering –** These organizations/groups contributed to defining end-user needs, ConOps or SyRS documentation.
- **Development –** These organizations/groups contributed to the build out of the project. This includes installation, integration, testing, and recruitment/outreach planning.
- **Demonstration –** These organizations/groups contributed to the operations and maintenance of a project from go-live to end of the demonstration.

Table 59: Project Stakeholders

Stakeholder	Systems Engineering	Development	Demonstration
Government			
City of Columbus Department of Public Service	X	X	X
City of Columbus Department of Public Safety		X	
USDOT	X	X	X
Columbus Metropolitan Library	X		X
Clinton Township		X	
Community-Based Organization			
St. Stephen's Community House	X		X
Active Linden			X
Mobility Provider			
COTA (property owner and mobility provider)	X		X
Mobility Providers (CoGo, Columbus Yellow Cab, Lime, Spin, Link)			X
Private Entity			
IKE Smart City	X	X	X
Educational			
Columbus State Community College	X		X
Tourism			
Experience Columbus	X		

Source: City of Columbus

11.3. PROJECT EVOLUTION

This section details how the SMH project evolved from its original conception during the development phase through the systems engineering process and to deployment. **Figure 11-8** summarizes the general timeframe for the project as it relates to SMH's major activities.

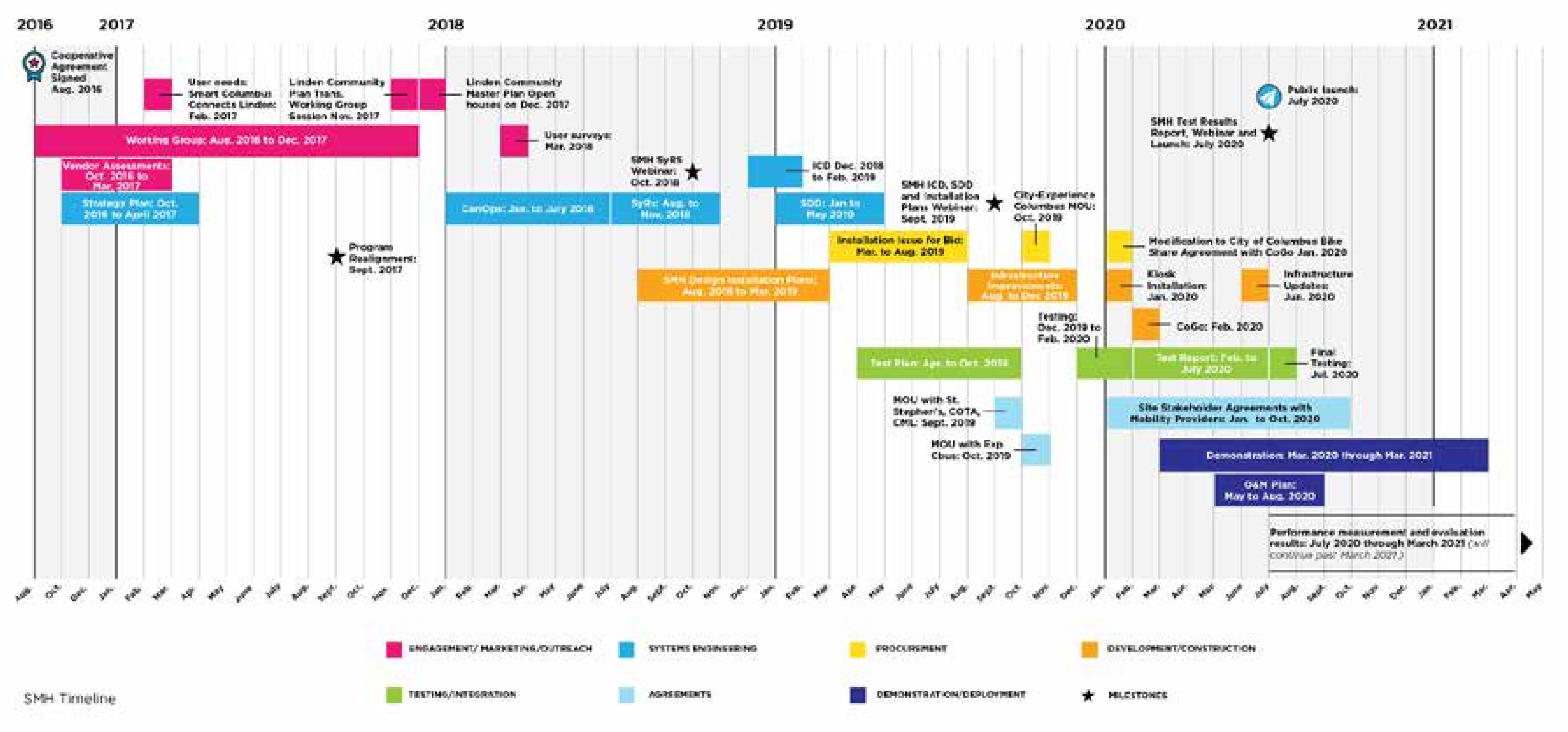


Figure 11-8: Smart Mobility Hubs Project Timeline

Source: City of Columbus

11.3.1. Scope – The Proposal

Volume 1 Technical Application for the Smart Columbus Program identified “Neighborhood Hubs” to support the COTA CMAX corridor and provide a variety of transportation options to facilitate FMLM connections, as well as access to the jobs and amenities that were cut off by the construction of Interstate 71. These multimodal service hubs were envisioned at the start to include the following components:

- Dedicated Short Range Communication (DSRC) radios
- Security features (CCTV and emergency call boxes)
- Multi-function kiosks providing transit service information, FMLM and vehicle sharing request and information, bike sharing information, and parking availability information
- Automated by-request shuttle service at Easton hub
- Wi-Fi hot spots
- Pedestrian detection
- Traveler information
- Payment kiosks

The City’s original Technical Application identified how the City intended to partner with COTA and one or more kiosk vendors to monetize its downtown kiosk installations to support a more robust kiosk installation in the Linden neighborhood and in support of the new COTA CMAX Bus Rapid Transit (BRT) project. The City would work with its procured vendor or vendors to install numerous kiosks downtown, and approximately ten kiosks at key locations in Linden and along the CMAX corridor to facilitate access to public transit, as well as transitions to other modes. These locations were envisioned as “Neighborhood Hubs” and would be located at key locations outside Linden to provide information access and trip planning to Easton Town Center, Columbus State Community College, and Downtown Columbus.

The Neighborhood Hubs would be used to facilitate FMLM travel by supporting a range of modal options. The City would expand the CoGo bike share service in Linden. It was proposed that a car-share partner would be engaged to provide access to this service. Finally, Neighborhood Hubs with parking facilities, like the Northern Lights Shopping Center, would enable car owners to transfer to the CMAX line, and avoid downtown parking and congestion. These parking facilities were to include electric charging stations to encourage electric vehicle use.

11.3.2. System Delivered

Through several workshops in the Linden Community, the project team determined that there were six preferred Smart Mobility Hub locations based on the input received and where the community saw FMLM gaps. To identify the mobility services to be provided at each site, the project team then transitioned to coordinating with the site stakeholders to deploy what was preferred by the property owners, and what fit within existing geometric constraints. The amenities at each of the six SMHs are outlined in **Table 11-6**. Continual stakeholder engagement was critical in transforming the high-level vision of SMHs into a product that would meet the real needs of the community.

Table 60: Amenities at Smart Mobility Hubs

	Amenities												
Location	IK	Wi-Fi	Park and Ride	Pickup/Drop-Off Zones	Car-Share	Bike-Share	Bike Racks	Dockless Parking	Real-Time Display	Comprehensive Trip-Planning	ECB	Electric Vehicle Charging*	Automated vehicle (AV) Shuttle**
Columbus State Community College													
Linden Transit Center													
Metro Library – Linden Branch													
Northern Lights Park and Ride													
St. Stephen's Community House													
Easton Transit Center													

= installed, = existing

**While defined in the SMH project documents, this was pursued outside of the scope of this project by COTA.*
***This is part of the CEAV project, another project in the Smart Columbus portfolio.*

Source: City of Columbus

THE CITY OF COLUMBUS ANDREW J. GINTHER, MAYOR

Figure 11-9: Traveler Undocks CoGo Bike-share at CML-Linden Branch

Source: City of Columbus

Table 11-7 describes the amenities deployed at the SMHs.

Table 61: Amenity Descriptions

	**Interactive Kiosk** The IK is a standalone touchscreen information device used to deliver a variety of services for travelers including: Ÿ **Traveler Information Service –** This service provides travelers transportation-related and community centric information services, including access to Pivot to plan multimodal trips. Ÿ **ECB –** This service provides a physical button affixed to the exterior of the IK that initiates a direct audio connection to the 911 emergency call center operated by the City of Columbus upon activation by the traveler. Ÿ **Wi-Fi –** This service provides complementary, publicly-accessible Wi-Fi at SMH locations for travelers using a personal wireless device to access the internet services.
	**Ride-Hail Pickup/Drop-Off Zone** Pickup and drop-off zones are available at select SMH facilities in the form of pull-off lanes and/or parking spaces located away from travel lanes that allow for the safe transfer of passengers for ride-hailing opportunities.
	**Car-Share** Car-share parking spaces are available at select SMH facilities for staging or parking car-sharing vehicles.
	**Dockless Device Parking** Designated zones are available for parking dockless devices, such as scooters and e-bikes, located at the SMH sites within the deployment boundaries of the devices.
	**Park and Ride** Designated locations are available at select sites that allow a traveler the option to complete a segment of his or her trip using a personal vehicle where he or she can use the SMH amenities to continue his or her trip using alternate modes of transportation like transit.
	**Bike-Share Docking Station** Physical locations were identified at most SMH facilities for docking stations for privately operated bike rentals using a back-end software system.
	**Bicycle Parking** Outdoor bicycle racks are a common short-term bike parking option offered at the SMH facilities for personal bicycles.
	**Bus Service** COTA provides bus facilities and vehicles along the Cleveland Avenue corridor. Most of the facilities were located at or near CMAX stations.

	Electric Vehicle Charging Station Free charging at the Northern Lights Park and Ride was provided through three electric vehicle stations and six J1772 Level 2 outlets through a deployment by COTA and supported by an installation grant through American Electric Power (AEP).
	AV Shuttle Service A shuttle service between the Linden Transit Center and St. Stephen's Community House SMHs providing a FMLM option for travelers, and demonstrating automated technology deployed by the City of Columbus through the Connected Electric Autonomous Vehicles (CEAV) project. The service operated for two weeks before a minor on-board incident paused passenger service, which was not restarted due to the pandemic. The shuttle service returned as a food pantry delivery service into the Rosewind Community, Central Ohio's largest public housing development.

Source: City of Columbus

11.3.2.1. CHANGES BETWEEN CONCEPT AND DEPLOYMENT

From the original application vision, the final delivered product did not include DSRC radios, pedestrian detection, or payment kiosks. DSRC and pedestrian detection did not surface through the public engagement process, so they were not viewed as user needs, and ultimately they were removed from the project. Payment kiosks, as originally described, would have been accommodated through COTA's Ticket Vending Machines (TVMs) that are located at limited COTA facilities. COTA indicated a hesitance to deploy more TVMs across the City and the TVMs did not surface as a user need through the public engagement, as the TVMs cited limited use. The TVMs were also removed from the project.

Some key takeaways from the SMH deployment are as follows:

- **Kiosks –** As the development of the Concept of Operations (ConOps) and SyRS progressed, the project team became aware of a kiosk deployment already underway within the City of Columbus. The original vision encompassed working with one or multiple vendors, and this was anticipated to be a procurement. However, with the planned deployment of kiosks around downtown and the Short North, the project team engaged kiosk contract holder Experience Columbus and kiosk vendor IKE Smart City to determine how to add the SMH locations to the deployment. The goal of the project team was to provide a consistent experience for all in Columbus, as any procured kiosks for the SMH that differed from the rest in the City could provide a negative perception. The kiosk system offered by IKE Smart City was vetted to verify that it met the requirements specified in the systems engineering documentation prior to installation.
- **Bike-Sharing –** Per the original scope, the project team worked with the site stakeholders and the existing bike-share provider (CoGo) team to determine the best locations for deploying new bike-share infrastructure. Looking at historical ride data, it was determined that the average trip on CoGo was one mile; therefore, the project team used that distance to locate which SMHs were the best candidates for a docking station based on the SMH's distance from another docking station. Columbus State Community College already had a bike-share dock, and based on the analysis, the project team identified three other locations: Linden Transit Center, St. Stephen's Community House, and Columbus Metropolitan Library – Linden Branch. The distance to Northern Lights Park and Ride was too great to recommend docking infrastructure, and Easton was significantly outside of the service area. However, during the project, the private developer of the Easton Town Center procured six CoGo bike-share docking stations and bikes for visitors to use around the area. The Easton Transit Center was situated less than one mile from the nearest new bike docking station, so the project team also included the Easton Transit Center SMH location in the bike-share deployment,

enabling visitors to Easton to ride transit and use bike-share rather than driving to Easton to then use bike-share.

- **Electric Vehicle (EV) Charging –** EV charging was envisioned in the original scope, particularly at the Northern Lights Park and Ride. The project team decided not to deploy this infrastructure on COTA's property but rather coordinated with COTA to have it secure a grant for the EV charging equipment through AEP. Therefore, this scope item was satisfied by other Smart Columbus leveraged partners.
- **Scooters –** A new addition to the mobility landscape that was not anticipated during the application and scoping process was the emergence of electric scooter sharing. These devices exploded onto the scene nationwide, and Columbus was no different. While some cities banned the scooters until regulations were developed, Columbus' leadership decided to allow the scooter operation to continue while working together with the mobility providers to develop the regulations. During discussions with the property stakeholders, the project team recognized the need to deploy designated dockless device parking areas to enable better site organization at the SMHs, expecting that this affordable transportation option would be attractive to many in the community. Therefore, the scope of the project was widened to accommodate this mode.

11.3.3. Site Stakeholders

Working with SMH site stakeholders was key to the success of the Smart Columbus Program. Each of the site stakeholders was responsible for the ownership and maintenance of their sites, and any improvements or access that the project was granted had to have minimal impact to the business operation of the site. Input and agreement were also required to finalize the physical design of the SMH, particularly where parking facilities, drop-off lanes, or other space-intensive uses needed to be dedicated to particular mobility services. Even in the instance of Columbus State Community College, where no improvements were on private property, the coordination between the project team and the stakeholder allowed the SMH to be installed in a fashion that did not impact the campus master plan and future improvements to the adjacent property. The site stakeholders also provided critical input on the modes available at each site. There were geometric constraints that prohibited some improvements, such as a park and ride where few parking spaces were available, or other considerations such as traditional bike racks leading to site clutter or other challenges.

11.3.4. Leveraged Partners

While the project team was finalizing the SyRS and preparing to develop procurement documents for the SMH, the team became aware of an existing agreement to deploy IKs throughout the City. Experience Columbus, the regional tourism agency, was the holder of the contract with IKE Smart City for kiosk deployment in Columbus. An evaluation was performed of the capabilities of the IKE Smart City product to determine if it met the needs identified in the ConOps and the SyRS. When it was determined that the product was appropriate for the SMH deployment, the project team entered into discussions with Experience Columbus to leverage its existing contract. Experience Columbus saw the potential of the SMH anchored with a kiosk and allowed a contract modification to include the six selected hub locations.

Since the IKE Smart City product is entirely advertising revenue supported, there was no cost to the City of Columbus for the installation of the six kiosks at the SMHs.

IKE Smart City played an important role in the development of the Interface Control Document, the System Design Document, and the testing procedures development. The project team needed to make the specifics of those documents, and the testing procedures, more granular and applicable to the system being deployed within the context of the SMHs. The project team regularly held meetings to discuss key developments and make decisions. Further, after IKE Smart City was on-boarded as the contractor, additional discussions finalized the location of the IKs, developed site access and power-sharing agreements, and determined where the power for the kiosks would come from – either from new connections to the public utility, or from the stakeholder buildings.

11.3.5. Challenges

11.3.5.1. PANDEMIC

The most significant challenge that impacted this project was the COVID-19 pandemic, as it was completely unexpected and unprecedented. The launch date for the project was targeted for early April 2020, shortly after the pandemic began to impact the United States, and around the time that Ohio began implementing restrictions. COTA also requested that all trips on its buses be limited to essential travel and reduced the routes, frequencies, and operating hours. Therefore, mobility in the Central Ohio region sharply declined. Even as businesses began to re-open and the travel restrictions eased, most of the travel in the region did not recover to pre-pandemic levels during the demonstration. The project team decided it was appropriate to launch the Smart Mobility Hubs in July so that those that did rely on public transportation for work could benefit from the services, recognizing that this would have a significant impact on data collection and performance evaluation. The full extent to which the project could have helped the community may not be known until travel and the economy begin to recover, and schools start to re-open.

11.3.5.2. PAYMENT AND BOOKING

The original scope and vision included payment kiosks, largely for purchases of COTA transit passes/fares. When developing the ConOps and SyRS, the project team identified that users should be able to book other modes of transportation from the kiosks to help bridge the technology gap. Through the SyRS phase, it was identified that the MMTPA would be installed on the kiosks and would provide access to a Common Payment System (CPS) to book trips. While the original plan envisioned all modes, technical challenges arose that led to limiting the modes available on the CPS. For instance, scooter companies need to know the location of the device and the user needs to lock the device at the end of the journey to complete the trip and end the billing. This relies on a traveler’s cell phone and was not feasible to complete using a stationary kiosk. The project team continued to explore modes that would work under this model and was pursuing CoGo bike-share, COTA transit, and Yellow Cab ride-hail. However, the CPS was removed from the Smart Columbus portfolio in the summer of 2020, resulting in payment options being removed from the SMH project. In addition, due to low usage, COTA expressed a lack of interest in deploying ticket kiosks at additional locations throughout the City beyond the few that existed when the program started. Therefore, standalone payment kiosks were not part of the final product delivered.

11.3.5.3. USB CHARGING

From the user needs sourced in the ConOps, it was proposed to provide USB charging at the Smart Mobility Hubs for travelers to add power to their mobile devices. During development of the Data Privacy Plan, a security audit flagged this item as a concern. With the USB charging located in the public space and unmonitored, it opened the door for nefarious activity utilizing USB skimmers. Skimmers collect the private information from a personal device and can provide it to someone with malicious intent. Therefore, the project team made a decision with project stakeholders to remove these from the project. Most sites provide building access where travelers could use a wall outlet to charge their devices.

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11.3.5.4. CAR-SHARE

When the scope was developed, car2go was operating a car-share in the City. As the project progressed, car2go ended its operations in Columbus, and Zipcar came into the City; however, the operations and deployment areas of Zipcar did not align with the SMH locations, so the project team and the mobility provider could not reach an agreement. The project team still dedicated space for car-share parking at some of the SMHs in anticipation of future car-share providers coming into the City and to provide dedicated parking locations for the Zipcar fleet for the users, understanding that car-share vehicles would not be staged at those locations.

11.3.5.5. AGREEMENTS

A challenge that was expected was the difficulty of executing all of the mobility provider agreements between the site stakeholders and the mobility providers. Each mobility provider needed to enter into an agreement with each site stakeholder where the amenity was to be placed on private property.

The project team recognized that since agreements would be necessary it would be best to have them as similar as possible across all stakeholders.

COTA was in the process of developing agreements for the agency's own mobility hub initiative, so the City worked with COTA to use its agreement as a model for St. Stephen's and the Columbus Metropolitan Library. By doing so, the level of effort to review the agreements from the City and mobility providers' perspectives was minimized. Even though there were minor differences in the agreements, at the core they were largely the same. With varying business models and different legal departments, it was originally expected that the agreements could take some time to be signed. The agreements were provided to the mobility providers for review, edits, and execution beginning in November 2019. Some of the agreements were signed as early as May and June of 2020. However, some took almost an entire year for execution, with COVID-19 having some impact on this timeline due to mobility providers reducing workforce. The length of time for executing the agreements was longer than anticipated. Not all of the agreements were signed by the launch, but at least one agreement for each type of mode was available when the project went live. Ultimately, the City of Columbus was not able to coordinate agreements between the site stakeholders and the Transportation Network Companies (TNCs) – Uber and Lyft – because they had their own vision on a national scale and did not want disparate agreements, terms, and layouts from city to city. Because the state regulates TNCs, the City had little leverage to encourage an agreement but was able to accommodate ride-hailing through Columbus Yellow Cab.

11.4. CONCLUSIONS, LESSONS LEARNED AND RECOMMENDATIONS

The service gaps that the SMH intended to address were as follows:

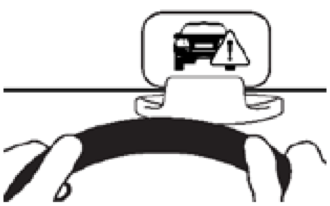
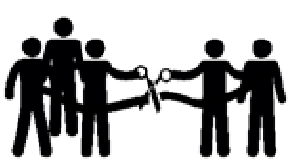
- Lack of physical facilities offering trip-planning, multimodal transit options, and other amenities at centralized locations
- Limited FMLM transportation options; these limitations make it difficult for transit-dependent residents to access basic services such as health care, grocery stores, and banking
- Inadequate optimization of ride-sharing
- Exclusion of unbanked users and users without smartphones from travel options
- Lack of adequate safety features like ECBs at transit facilities

Through the visioning, design and deployment phases, the project team was able to address all of the gaps to some degree except for the exclusion of unbanked users and users without smartphones from travel options. The gap was largely intended to be addressed through the inclusion of the MMTPA/CPS on the kiosks. As the MMTPA/CPS project developed, challenges arose with enlisting mobility providers in the CPS and that part of the project was removed from the Smart Columbus Program. In addition, it became evident that it was not feasible to facilitate the unlocking of some mobility options, such as dockless scooters or ride-hailing service, away from the IK without a smartphone. These modes have been developed with the smartphone at the core of the system architecture, and few mitigations exist to accommodate the lack of a smartphone, especially ones that would align with the design of the MMTPA.

The SMHs continue to provide modal choices and mobility information for travelers to reach their destination. SMHs may require ongoing coordination with stakeholders, such as private businesses, COTA, and the Department of Recreation and Parks. The Department of Public Service will take ownership of the SMH project and coordinate further implementation. Additional neighborhoods and mobility corridors are being studied as part of the City's mobility plan, LinkUS. Opportunities to include SMHs in LinkUS will be identified and implemented using the framework developed by the Smart Columbus Program and COTA's mobility hub program. The existing sites have agreements with the private property owners to ensure they continue beyond the demonstration.

The SMH project addressed the City challenges and met the original expectations defined in the City's Smart City vision. The project addressed transportation challenges by deploying applications and strategies in the following USDOT's vision elements in **Table 11-8**.

Table 62: Smart Mobility Hubs Project Relationship to USDOT Vision Elements

VISION ELEMENT #3 Intelligent, Sensor-based Infrastructure 	Deployed IKs that integrate Pivot and bike-share docks that report the number of available bikes.
VISION ELEMENT #4 User-focused Mobility Services and Choices 	SMH deployed ten different mobility enhancements across six sites to give travelers options.
VISION ELEMENT #7 Strategic Business Models and Partnering 	Partnership with Experience Columbus enabled kiosks to be deployed at no cost to the City, in addition to partnering with site stakeholders at the six hub locations. Overall a low-cost project that through a private-public partnership deployed informational kiosks to enhance mobility.

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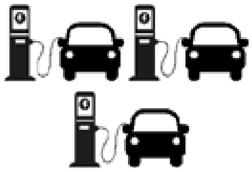
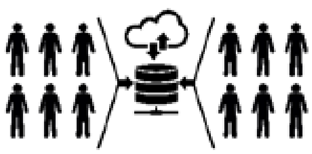
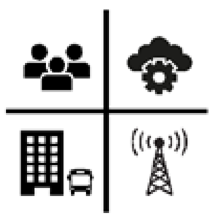
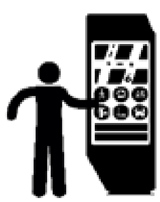
VISION ELEMENT #8 Smart Grid, Roadway Electrification, and Electric Vehicles 	Through coordination with COTA, the project deployed EV charging at the Northern Lights Park and Ride.
VISION ELEMENT #9 Connected, Involved Citizens 	With the installation of the kiosks at the SMH, the project was able to provide technology access to help bridge the digital divide, as well as Wi-Fi access points to address those with limited access to data plans or internet.
VISION ELEMENT #10 Architecture and Standards 	Developed ITS architecture using Architecture Reference for Cooperative and Intelligent Transportation (ARC-IT) / Systems Engineering Tool for Information Technology (SET-IT) for the repeatable deployment of mobility hubs.
VISION ELEMENT #12 Smart Land Use 	Brought together technology, transit sites, privately owned land, and existing right-of-way in support of transit-oriented development by maximizing mobility options to support of CMAX BRT with FMLM connections.

Source: City of Columbus

11.4.1. Conclusions

- Public and stakeholder input is critical to identify the transportation challenges and needs of the residents and business community.
  - Engaged with stakeholder groups and residents to identify locations where better transportation and technology access would benefit the community to address issues in safety, mobility, and access to opportunity.

- The deployment of the SMHs was inexpensive considering significant construction was not required, with expenses of approximately $250,000 on infrastructure (concrete, signage, pavement markings) and bike-share stations and bikes to deploy six SMHs.
  - Coordinated with COTA as it applied for an AEP grant for EV charging at Northern Lights Park and Ride
  - The City of Columbus was able to leverage the existing kiosk contract that is advertisement-supported to install the six kiosks at no cost to the City.
- Once a vision for the project concept, user needs, and participating mobility providers are identified, the construction of the sites can be accomplished quickly: in the case of the SMH, site survey, design, permitting, and construction can be accomplished in months if using in-house forces to construct.
- There are opportunities to seek efficiencies in contracting and delivery:
  - Creating one similar site access contract that was used by all site stakeholders worked for all parties and reduced the need for each mobility provider to review up to three different site access contracts.
  - Even with unified contracts, the SMH project team spent several months negotiating and executing the first mobility provider agreement, with remaining agreements taking up to a full year to execute. Reaching agreement between stakeholders and mobility providers requires careful schedule budgeting and continuous communication and coordination between the parties.
  - Leveraging partners and existing agreements and contracts, such as the existing city-wide IKE Smart City kiosk agreement with Experience Columbus, to avoid a lengthy procurement process.
- The project installations extended mobility accessibility into Linden, provided access, allowed residents to live their best lives. The CoGo for All program connected affordability of bike-share with the access provided through the Smart Columbus Program. CoGo for All provides eligible participants with a $5 annual membership and unlimited 45-minute classic bike trips ($.05 per minute for rides longer than 45 minutes). The program is available to all Central Ohio residents, aged 18 and older that receive Medicaid, SNAP (WIC, EBT, and EBT), or a discounted utility bill.

Bike-Share Provides First Mile/Last Mile Connections from Smart Mobility Hubs

"By placing CoGo Bike Share stations at Smart Columbus Mobility Hubs, we are able to integrate an important first mile/last mile solution for the Linden community that helps residents complete connections to the greater transportation network and links them to essential resources like healthcare, libraries, groceries and jobs."

Chet Ridenour, CoGo Bike Share Operations Manager

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11.4.2. Lessons Learned

- Schedule delays should be accounted for in project planning, with contingency included if possible. In the case of the SMH project, specific examples of delays that include:
  - Specific requirements for IKs – such as specifying an indoor unit with the ECB – delayed delivery and installation. The indoor units are slimmer due to the absence of heating and cooling elements.
  - Even with an existing bike-share contract, delivery of the bike-share docking stations took more time than anticipated due to the ordering process of the vendor amongst its various cities.
- Emerging technologies demand adaptability in deployment. Many of the emerging modes, such as scooters, e-bikes, and car-shares are new businesses that can quickly enter and exit the market. Accommodating these modes requires:
  - Flexibility during the project development and design process. In the case of the SMH project, there were several examples:
    - The project had to accommodate scooters after they arrived in Columbus.
    - CoGo bike-share expanded its deployment area into Easton and enabled the City to increase the mobility options at the Easton Transit Center SMH.
    - One car-share company left the Columbus market. Another entered; however, it did not express interest in the project sites. A third car-share provider is currently entering the market and does have interest in deploying vehicles at the SMH sites.
  - Accounting for plan adjustments, since some final locations can change during the final permitting phase due to access to power, specifically with the kiosks.
- Solidifying mobility providers' participation requires clear definition of terms and the projection of potential benefits though the project may not tie into their larger business models. For example:
  - Not all mobility providers wanted to participate in the program and the City had little control over the situation, particularly the providers that are not regulated at the City level like TNCs (Uber and Lyft), though ride-hailing was satisfied through Columbus Yellow Cab.
  - Some mobility providers did not want to enter into agreements with private entities nor did they want a lack of consistency from city to city of how they approach mobility hubs nationally.
  - While some leg work can be done up front to educate providers on what an agreement may look like, most were unwilling to consider/finalize participation until exact terms are determined.
- It is especially important when advancing technology and mobility projects, especially those that are integrating multiple modes, to use a unified technology approach so that the efforts and projects taking place elsewhere in the agency and through other funding sources can be leveraged and brought together for the benefit of all stakeholders and projects. For example:
  - Kiosks were being deployed across the City by the City's travel and tourism agency. Using the same kiosks that met a majority of the requirements presented a consistent approach to technology deployment in opportunity neighborhoods.
  - It made sense for property owners to leverage other available grants for EV charging so the City supported and encouraged COTA to take the evolutionary and revolutionary steps to integrate charging into the management and operations of locations with parking including Northern Lights Park and Ride.

Interactive Digital Kiosks are a Smart Solution to Mobility Challenges in Columbus

When planning the launch of an IKE network in a new city, one of IKE Smart City's goals is to equitably distribute the kiosks in locations that are easily accessible to the public. Installing digital wayfinding kiosks in the Linden neighborhood of Columbus, OH, where Smart Mobility Hubs were located, was a critical component in solving the complex transportation and mobility challenges found in growing urban populations. Amongst its many features, IKE offers comprehensive wayfinding tools, including maps, step-by-step directions, and real-time transit information such as bus schedules, scooter and bike-share availability, and multi-modal travel times.

Consistency is important to community adoption of interactive digital kiosks. Deploying a cohesive network of wayfinding kiosks as Columbus has done provides users with the same experience at each kiosk location. This approach builds familiarity with and affinity for the platform so that the public can easily find and use the kiosks as they navigate from place to place throughout the city.

Randall Sistrunk, Director of Development, Orange Barrel Media and IKE Smart City

- Even in a pandemic, the importance of communications throughout the process should be stressed. For the SMH project, while it was difficult to measure the impact of communications due to lack of interest in shared rides during the pandemic, the communications efforts of the project team throughout the process not only were critical to gaining and sustaining partner involvement, they are also setting the project up for sustained success by educating the community on awareness and understanding new options and tools.

11.4.3. Recommendations

For agencies considering the deployment of mobility hubs, the SMH project team recommends:

- Align goals and locations early in the process with stakeholders, as user needs may grow and may change from what is first gathered. To the extent feasible, stakeholders should remain engaged as the project continues development so that changing needs can potentially be incorporated. Be adaptable to changes during design, construction, and deployment as well as the systems engineering process to accommodate the pace of emerging technologies.
- Develop standardized stakeholder agreements between public and private entities, where applicable, for quicker legal review time. These agreements will facilitate construction on the site and should address the sustainability of the site.
- Coordinate with mobility providers regarding the project vision and the business case: mobility hubs are the building blocks for Mobility as a Service (MaaS). This can help align mobility providers to participate in the program, though not all mobility providers will align and instead pursue their own path.
- Identify the data desired and have discussions with partners to assure they can be collected to measure the performance of the mobility hubs as well as build the business case for future scaling of the project and engagement with mobility providers.

- Identify a champion and long-term owner to develop a public-private partnership; this will make agreements and outreach easier and promote the scaling hubs around the city for the mutual benefit of both businesses and residents.

11.5. SUMMARY

The SMH project combined traditional systems engineering methods (V-Model) while leveraging innovative partnerships (Experience Columbus and Orange Barrel Media and its IKs) to complete the project on schedule and within budget. Unanticipated challenges centered on the planning and coordination required to solidify agreements with site stakeholders and participating mobility providers, and, of course, the impact of COVID-19 which delayed the launch and altered the communications strategy around user adoption.

Despite these challenges, however, the six SMHs launched with minimal delay, and will be sustained after the Cooperative Agreement ends and become part of the mobility ecosystem in Columbus. The SMHs are a support service to enable MaaS deployment, and as travel returns to the region, it is anticipated that mobility hub use will increase. These continued lessons learned will support growth and further deployment of SMHs across the City to enable transit-dependent residents to better access basic services such as health care, grocery stores, and banking.

Chapter 12. Event Parking Management

12.1. PROJECT OVERVIEW

Every successful, growing city has concerns over downtown parking, and Columbus is no different. In the City's Downtown and popular Short North district, drivers expect to circle the block a few times before finding an available parking meter, leading to frustration, lost time and wasted fuel. To make the Downtown and Short North areas easier to visit, a one-stop-shop for parking information was needed to serve residents and visitors.

The Event Parking Management (EPM) project solution was ParkColumbus – a web- and app-based solution that provides public and private parking information, including rates and access to driving directions to make parking easy. ParkColumbus also offers the ability to pay for and extend on-street parking sessions, as well as make on-demand purchases and reservations at private garages and surface lots. Another key feature of ParkColumbus is its parking prediction model that displays the likelihood of finding available on-street parking on a given block. While the ParkColumbus app was already being used by the City to pay for on-street parking, the EPM project added extensive functionality and a website. The launch of the new functionality started in July 2020, with the final rollout of features wrapping up in early 2021.

The amenities in **Table 12-1** show the size and scale of the parking assets included in the project.

Table 63: Event Parking Management Project Scope

Scope	Description
Parking garage and surface lot spaces	The project captures parking availability and other data from 86% of the available parking garages and private surface lots in the project area and transmits the data to the EPM Central System and then to the Smart Columbus Operating System (SCOS).
Parking meters and kiosks	The project collects parking-related data from approximately 4,300 single-space parking meters and nine kiosk payment parking zones and transmits the data back to the SCOS to predict availability.
Loading zones	The project collects restriction information for approximately 130 loading zones designated by the City of Columbus.
EPM Central System	The EPM project consists of several new software modules working together to deliver the EPM service, including a front-end traveler user interface and back-end central system that connects, captures, relates, stores, and responds to real-time parking data collected from various sources and equipment. EPM interfaces with the SCOS to house real-time and archived data and allows stakeholders operational and reporting access. These combined software modules make up the EPM system, providing current, projected, and complete views of parking status and availability to help travelers plan and pay for parking and realize the City's smart parking vision and goals.

Source: City of Columbus

The City's Division of Parking Services (Parking Services) was the first to join the EPM project team. Parking Services manages all on-street parking and would be the final owner of the EPM system. The project team also partnered with Experience Columbus, which had already been meeting with parking operators in the Downtown and Short North areas to discuss parking and tourism. Parking operators were an essential component of the EPM's success because they agreed to allow their parking assets to be added to the City's ParkColumbus application. Finally, ParkMobile was chosen as the vendor after it was selected as the City's on-street mobile payment vendor and demonstrated the ability to meet the needs of EPM. Having a second parking application for the City would be both inefficient and confusing for users.

The geographic scope of the EPM project, shown in **Figure 12-1**, focused on the Downtown and Short North areas given their dense population and great need for parking for employees, tourism and residents.

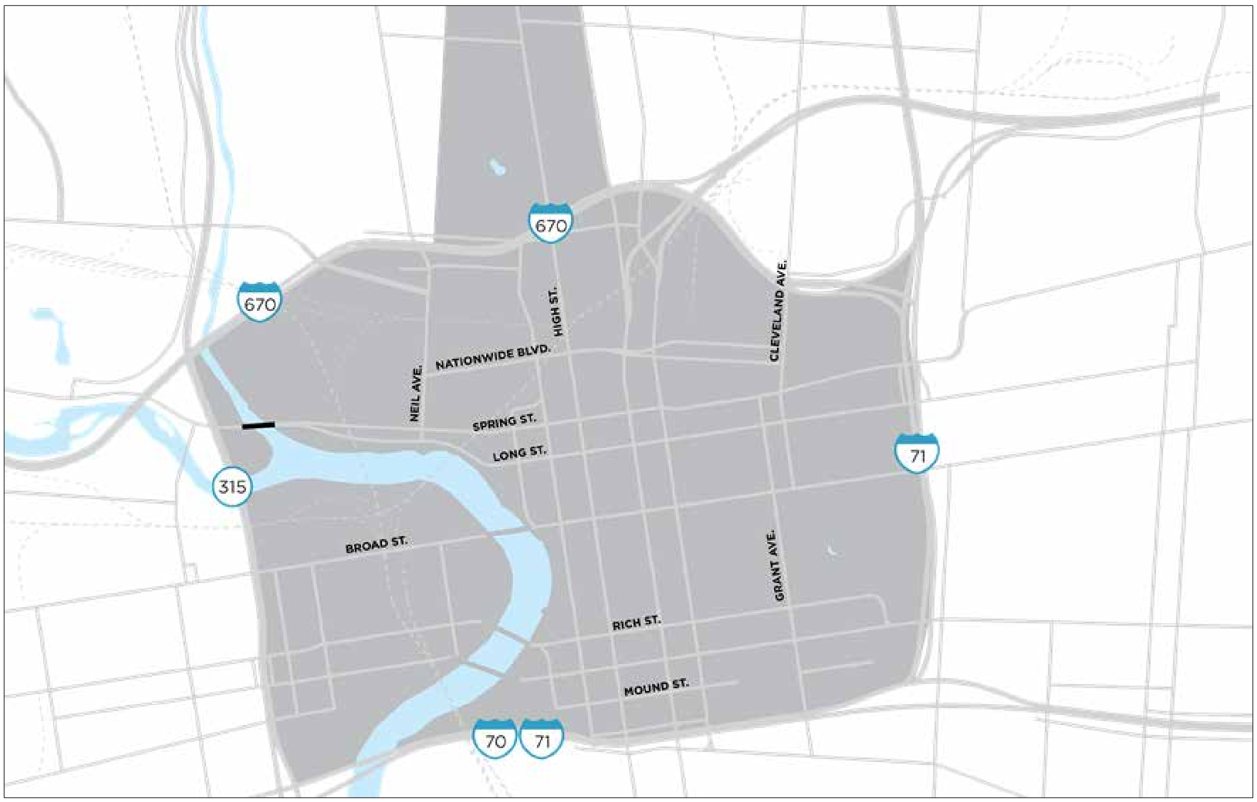


Figure 12-1: Event Parking Management Geographic Scope

Source: City of Columbus

12.2. DEPLOYMENT SUMMARY

12.2.1. Systems Engineering Approach

The EPM project began development using the V-Model methodology, where the project team developed the project's Concept of Operations (ConOps) and System Requirements Specification (SyRS). After procurement, the vendor used an Agile development methodology to deliver the EPM system requirements. Both these approaches are described in **Chapter 2**.

The EPM project's Hybrid approach, where the project pivoted from V-Model to Agile after system requirements, was chosen to allow incremental development, testing and releases. ParkMobile used the

ConOps and SyRS developed by the EPM project team to plan the releases by which the functionality described in the systems engineering documentation would be rolled out. The Agile approach allowed the functionality to be developed and deployed to the public incrementally, getting the features out sooner.

As each release was delivered to the City, the EPM project team performed user acceptance testing to validate delivery of functional system requirements.

Figure 12-2 captures the traditional V-Model with the overlay of the Agile development duties broken out by team. As the project transitioned into operations and maintenance, both the EPM project team and vendor team worked together to plan, conduct and monitor the project.

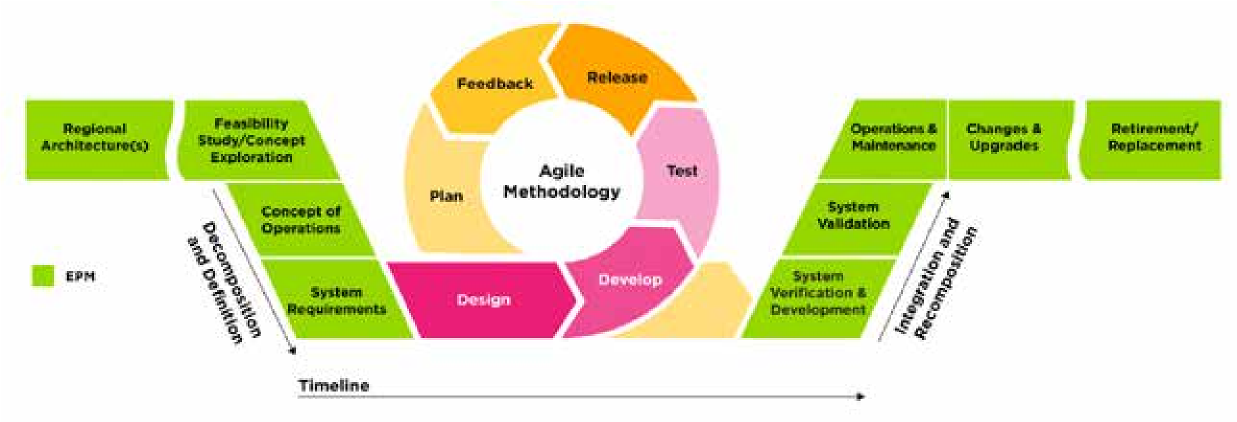


Figure 12-2: Event Parking Management Systems Engineering Delivery Responsibilities

Source: City of Columbus

Figure 12-3 summarizes the general timeframe for the EPM project's major activities.

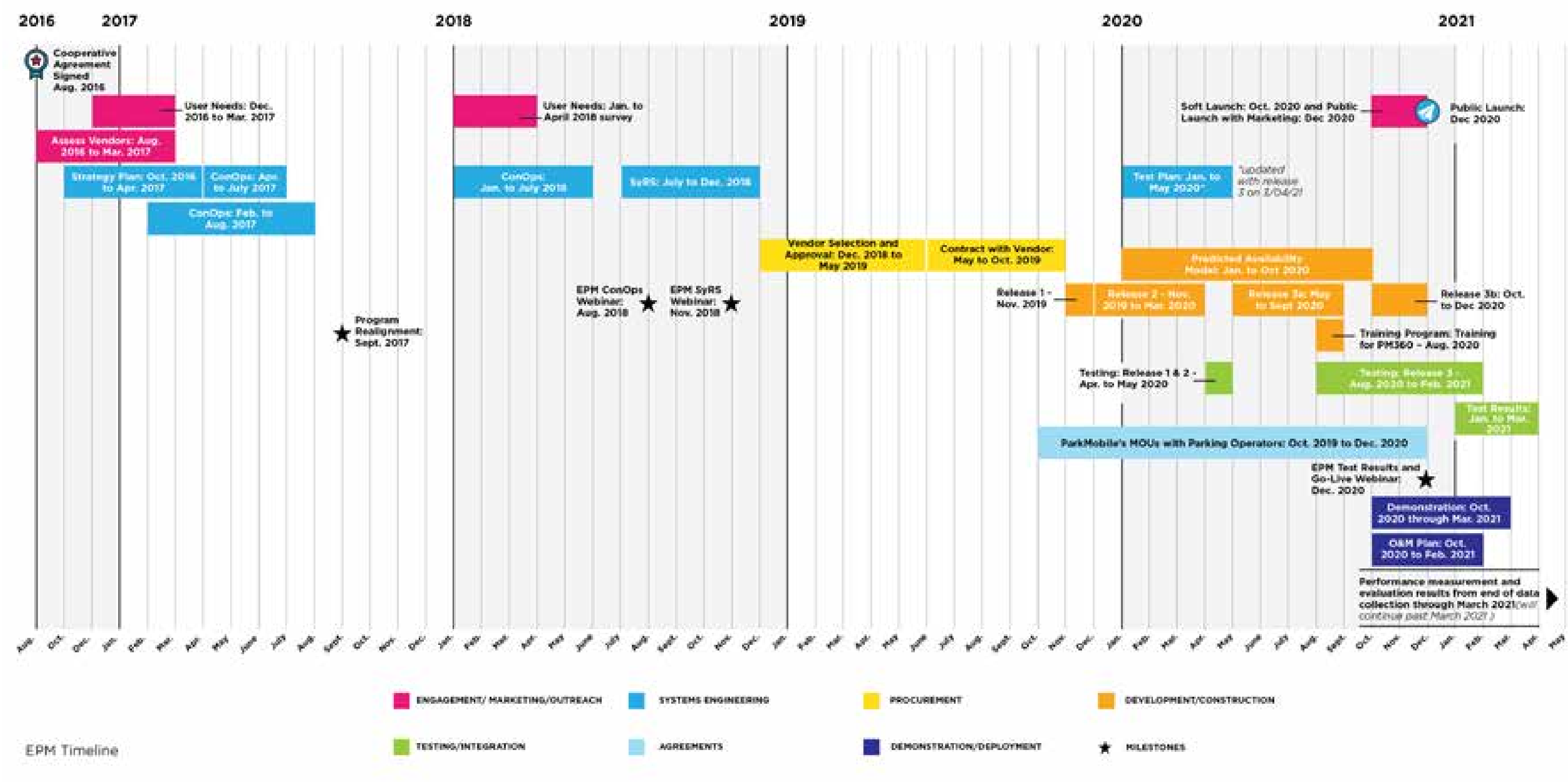


Figure 12-3: Event Parking Management Project Timeline

Source: City of Columbus

12.2.2. Project Launch

The pandemic significantly impacted the EPM project's recruitment efforts and the public launch, originally scheduled for May 2020. These efforts were essential to promoting adoption. However, the City did not want to release and promote an app dedicated to parking and traveling while so many in Columbus were struggling with job loss, travel restrictions, and concerns about their personal health and safety. More importantly, parking demand had plummeted in Downtown and the Short North, and businesses were utilizing "curb service" to find creative ways to serve the public using on-street parking spaces. All these factors encouraged the team to push the launch to July 2020.

Through the early summer, it was clear that parking demand was still low; so, the project team decided to launch Releases 1 and 2 without a campaign to recruit new users and make existing users aware of the improved app. The July launch included updates to the public ParkColumbus app, and the creation of a website which included guest checkout for reservations. The hope was that by fall, COVID-19's impact on parking demand would diminish but given the long-term impacts COVID-19 had on parking, the team decided a new baseline survey[114] would ensure the survey data collected for customer satisfaction was valid.

The new survey focused on establishing a new baseline for awareness of parking options in the area as well as to capture changes in travel due to COVID-19. After the new survey was completed, the October release was launched on the app and website on October 28, 2020. The focus of the October launch was the addition of the parking prediction model to the app. The backend account view for parking administrators, PM360, also came with this release. As was the case in July, this technology launch was done without an awareness campaign due to the high cost of promotion and consideration of any advertising getting lost in the presidential election campaign.

On December 9, 2020, a public press release was issued to announce the new app features that were added earlier in the year to promote awareness and use of the app. Additional functionality was released to the public in March 2021, consisting of new filtering features for on-demand parking, a Spanish language option for the mobile app, and on-demand parking information on the website.

12.2.3. Demonstration

After EPM's July 2020 launch, the project continued to develop new features and roll them out based on the schedule shown in **Figure 12-3**.

Table 12-2 lists the number of new downloads since July 2020.

Table 64: ParkColumbus New Downloads

Month and Year	Number of New Downloads
July 2020	7,903
August 2020	11,410
September 2020	9,548
October 2020	9,360
November 2020	5,952

[114] *A survey was conducted in April 2018 to collect user needs for the ConOps.*

Month and Year	Number of New Downloads
December 2020	5,761
January 2021	7,019
February 2021	6,944
March 2021	10,701
April 2021	10,987

Source: ParkMobile

Since March 2020, project data, including retroactive data, was shared with the SCOS. Previous parking meter transaction data was also available to EPM and the SCOS. As **Figure 12-4** shows, parking meter transactions dropped in March 2020, when employees were sent home due to the pandemic and have not recovered to pre-COVID levels.

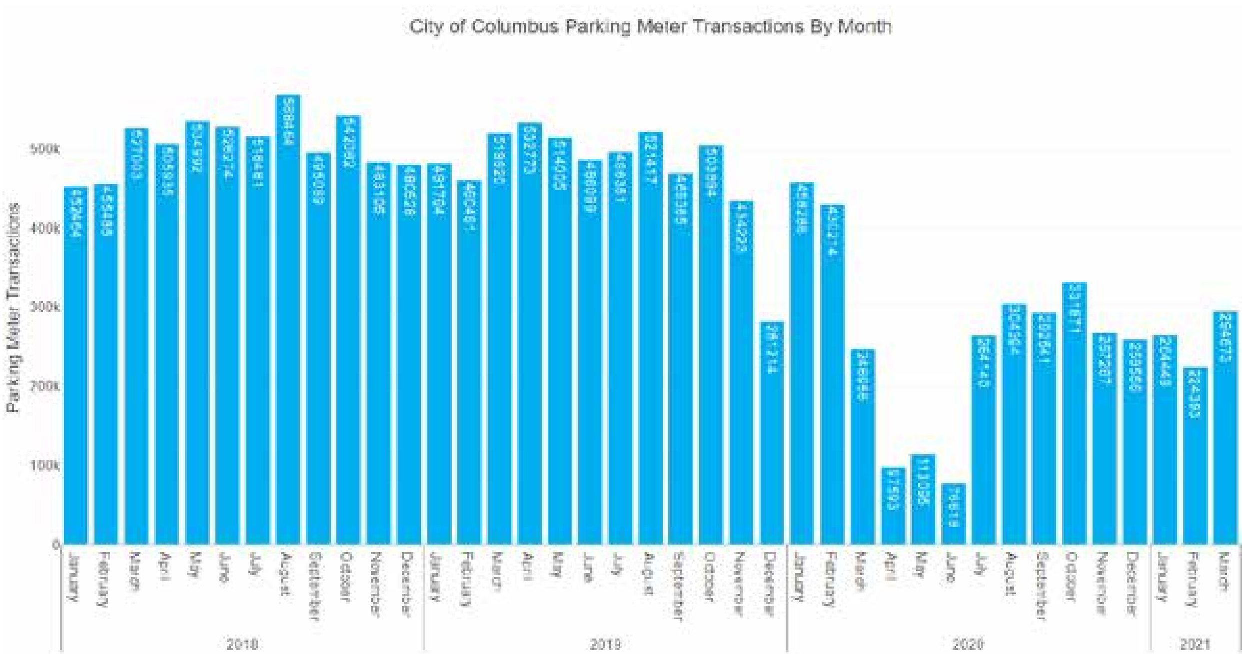


Figure 12-4: City of Columbus Parking Meter Transactions by Month

Source: City of Columbus, https://discovery.smartcolumbusos.com/visualization/gf2sz0ux

As **Figure 12-5** shows, the pandemic impacted the payment method for on-street parking. Cash was the primary method before May 2020. Both payment types increased from July through September, but since October, credit cards became the primary payment type as cash payments continue to decline.

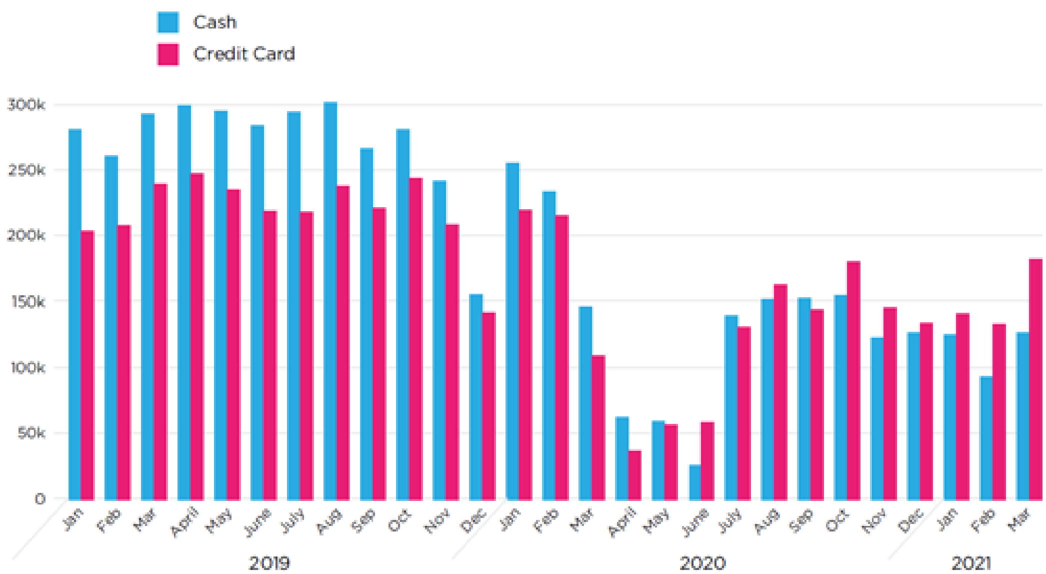


Figure 12-5: City of Columbus On-Street Transactions by Payment Method

Source: City of Columbus, https://discovery.smartcolumbusos.com/visualization/jnjtrj1t

Since the launch of the ParkColumbus app, the share of credit card payments made within the app for on-street parking has grown rapidly, and now exceeds the use of credit card payments made at the meters, as shown in **Figure 12-6**.

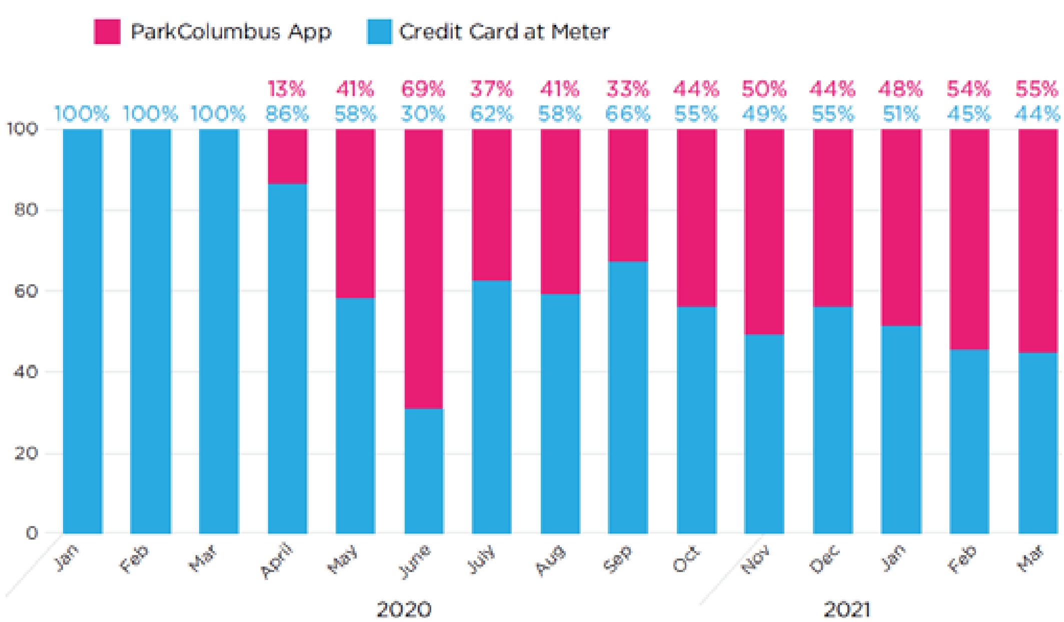


Figure 12-6: Parking Meter Credit Card Transactions by Payment Source

Source: City of Columbus, https://discovery.smartcolumbusos.com/visualization/zmru4wch

EPM was originally meant to focus on alleviating parking concerns during major events (downtown Columbus boasts a major league hockey arena, a minor league baseball park, and several theater venues). However, due to the pandemic, very few events occurred during the demonstration, and those that did such as hockey games at Nationwide Arena, had limited capacity and did not induce a sufficient parking demand that users would need the reservation service. As events return to full capacity and the new Columbus Crew soccer stadium is set to open in July 2021, the reservation feature is expected to grow in use.

The number of parking garage reservations made through ParkColumbus are shown in **Figure 12-7**.

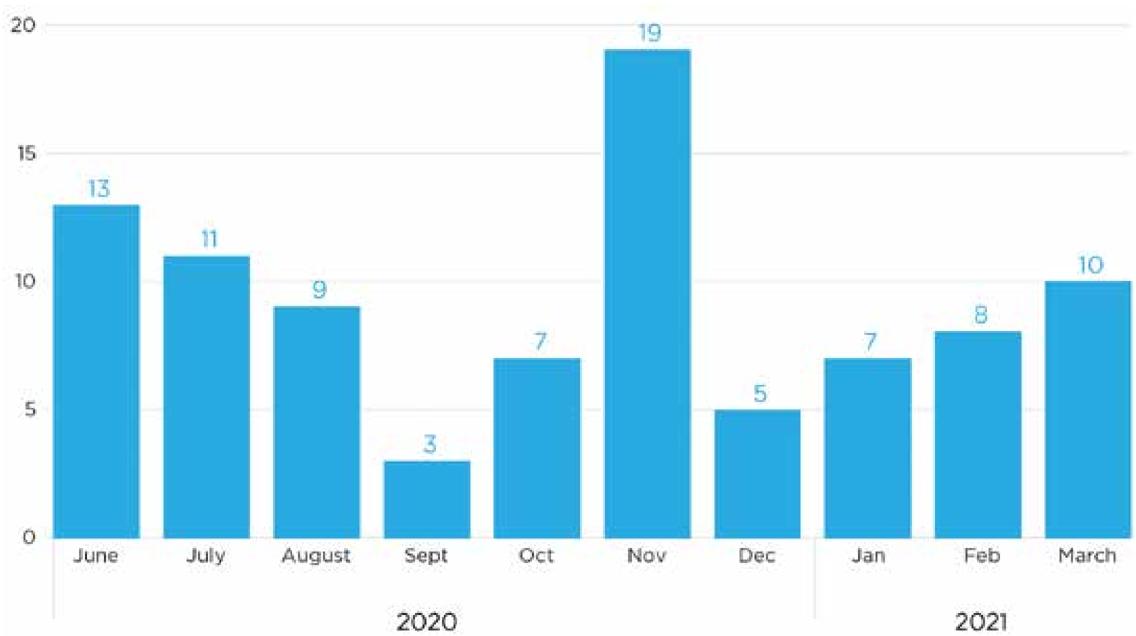


Figure 12-7: ParkColumbus Parking Garage Reservations By Month

Source: City of Columbus, https://discovery.smartcolumbusos.com/visualization/w6bq7u5k

To ensure the sustainability of the EPM project, Parking Services was identified as the long-term owner, and had been involved since project concept development. EPM supports Parking Services' mission to provide "accessible, equitable and predictable mobility and parking options for all residents, guests and visitors. The aim is to reduce congestion, increase mobility options and manage parking in a city experiencing enormous growth, while preserving the uniqueness of the City's neighborhoods for all to enjoy."[115] Parking Services was also involved with the program restructuring in 2017 wherein two parking projects were removed from the portfolio: Delivery Zone Availability (DZA) and Enhanced Permit Parking (EPP). DZA was focused on showing the location, restrictions, and availability of loading zones within the City of Columbus, to assist drivers of delivery vehicles. The EPP project was concentrated on using virtual permitting, online permit management, and license plate recognition to replace an outdated permit management system.

In 2018, Parking Services implemented an all-virtual permit parking system in the Short North. This comprehensive approach transitioned a system of permit stickers and hangtags into the use of virtual permits and online account portals to apply for and manage permits. Parking Services also worked with ParkMobile and Conduent, another parking technology vendor, to implement virtual 24-hour guest

[115] https://www.columbus.gov/publicservice/parking/Parking-Services-Home/

permitting, the first in the parking industry. This technology required the back-end permitting system, the mobile payment app, and the citation management system to communicate guest pass code issuance and use of those codes so that parking enforcement officers had the ability to properly enforce. Parking Services also implemented license plate recognition to efficiently enforce permit parking and paid parking. Parking Services is currently working to get other permit areas on the virtual platform.

In 2019, Parking Services completed a comprehensive Strategic Parking Plan (SPP) which included descriptions of the goals identified in the EPP and DZA projects. From the SPP, Parking Services conducted a CurbFlow pilot from January 2019 to March 2020 which further evaluated the ability to designate loading spaces based on data from several freight carriers and on-demand delivery services to provide access in high demand areas and to better manage the curb space. The pilot also included an enforcement component that included sending violation data to parking enforcement officers and monetizing the curb. While the effort was successful overall, the monetization component never came to fruition due to constraints with CurbFlow and City fiscal processes. However, Parking Services released a Request for Proposal (RFP) for Dynamic Curbside Management in March 2021 to replace the existing outdated loading zone system.

Also in 2019, Parking Services piloted three different types of parking sensors at meters in the Short North. Staff tested two in-ground sensors and one meter-head sensor to determine their overall accuracy and reliability in detecting vehicles. These sensors communicate real-time parking availability data to the vendor's backend system that can be viewed by staff. One in-ground sensor provider shared the sensor output data with the SCOS to be used in the EPM parking prediction model. The same sensor data is also shared with the public in the SCOS.

12.2.4. Communications

12.2.4.1. STRATEGY AND GOALS

The communications team employed a multichannel recruitment and adoption approach that involved combining traditional and digital communication channels, and then maximized reach through stakeholder and other community engagement efforts. The communications goals for EPM included increasing knowledge about parking options in Downtown and the Short North and awareness of the ParkColumbus app as a parking tool.

12.2.4.2. AUDIENCE AND MESSAGING

With all major events canceled, stay-at-home orders in place and demand for parking at an all-time low, the communications team adjusted its strategy to focus on reaching people still active in the area, rather than driving new people to the area. The audience was defined as people who already drive to and park in Downtown Columbus and the Short North. Another communications challenge was that the ParkColumbus app initially launched with just the parking payment options feature prior to the new Smart Columbus features being added as part of the EPM project. That meant that ParkColumbus already had significant market saturation prior to this project's outreach efforts, making it harder to attract new users.

The key messages included:

- New features powered by Smart Columbus are now available in the ParkColumbus app that make it easier than ever to park in Downtown Columbus and the Short North.
- Find, reserve and pay for parking in participating garages and surface lots.
- View the likelihood of finding an on-street parking spot.
- Identify specialized types of parking such as Americans with Disabilities Act (ADA) accessible and electric vehicle (EV) specific spaces.

- Quick pickups and drop offs are easier than ever with access to loading zone locations.
- Access new ParkColumbus features on the web – no app download required.
- Avoid frequently touched public surfaces with reservation, payment and routing all through a smartphone via the ParkColumbus app.

12.2.4.3. PRELAUNCH

Prior to launch, the communications team worked with key stakeholders including Experience Columbus, the Short North Alliance, and the downtown Capital Crossroads and Discovery Special Improvement Districts (SIDs) to ensure they were updated as the project was developed. The communications team also supported briefings with participating Parking Operators to keep them updated on project progress (see **Figure 12-8** taken in Fall 2019).

Figure 12-8: Parking Operators Meeting

Source: City of Columbus

12.2.4.4. LAUNCH

The EPM project was launched publicly via a press release and supporting videos from the Mayor, Program Manager, and Chief Executive Officer of Experience Columbus. The videos were shared and promoted on social media from the Smart Columbus Facebook page. Additionally, a “what’s new” email (see **Figure 12-9**) was sent to existing ParkColumbus users, and a pop-up was added to the app so when a user opened the app after the upgrade, information was shared about the new features added as part of the EPM project. The communications team also worked with the City to update content on the Division of Parking Services and Smart Columbus websites.

Figure 12-9: ParkMobile "What's New" Email Sent to ParkColumbus Users

Source: ParkColumbus

Between December 9, 2020, and March 31, 2021, the following paid, earned, owned, and shared tactics described in **Chapter 3** were used to communicate about the new features in ParkColumbus and recruit new downloads.

12.2.4.5. PAID

An email and social media sponsorship package with Columbus Underground that ran as part of a holiday shopping promotion encouraging buying from local retailers. The promotion occurred from November 11, 2020 through December 18, 2020. The package of five advertisement pieces was distributed in 18 total increments via emails to local subscribers and this resulted in 57,491 impressions (including views, email opens and click-throughs). **Figure 12-10** shows a sponsored tweet that was part of the advertising package, which generated an additional 3,899 impressions for a combined total impression of 61,390.

Figure 12-10: Columbus Underground Twitter Ad

Source: City of Columbus

In conjunction with the digital holiday promotion package through Columbus Underground, an advertising buy was purchased on local popular independent radio station CD 92.9. From December 15-28, 2020, 120 total 30-second spots ran. The station's total listenership on radio is 145,700 and on its digital platform the reach is approximately 150,000 individuals.

During the timeframe where the Columbus Underground and CD 92.9 advertisements ran, ParkMobile estimates a total 7,024 new ParkColumbus user registrations (1,610 Android and 5,414 Apple).

In January and February 2021, the communications team opted strategically to engage via owned and shared recruitment tactics. In March 2021, two additional media buys took place on social media – one via social media platform NextDoor and the second with local partner the Short North Alliance. Over 14 days, from March 18 through March 31, 2021 the advertising program generated 39,254 total impressions (an average of 2,804 per day) and 66 unique click throughs (an average of four per day). This click-through rate of 0.17% exceeded NextDoor's performance expectation of 0.15% for this geography during this timeframe.

Secondly, in partnership with the Short North Alliance, a sponsorship was purchased that included an online contest where those who downloaded and used the ParkColumbus app had the chance to win gift cards to local businesses. The combination of Facebook, Instagram and Twitter exposure generated a reach of 20,311 unique visitors and a total 82,563 impressions. There were 171 total contest entries, or qualified downloads that resulted from this contest.

Figure 12-11: Online Advertisement for ParkColumbus Updates

Source: City of Columbus

12.2.4.6. EARNED

The EPM project launch included a press release with video content that generated media coverage by two outlets – The Columbus Dispatch and Columbus Underground. Additional proactive media opportunities were not available around this time and for the following months due to major national story lines that took media focus away from the EPM project. Therefore, the communications team selected to move to better performing communications tactics via paid, owned and shared mechanisms.

12.2.4.7. OWNED

The communications team used several tools to promote the EPM project through its owned channels. In conjunction with Parking Services, signage was placed at 200 parking meters within the project zone.

In addition, ParkMobile pushed out an email blast to existing ParkColumbus users to engage them in looking into and using the new features. The email was distributed to 94,000 addresses with an open rate of 37% and a click-through rate of 1.5%.

The Smart Columbus Program communications team promoted the EPM project on its social media platforms in strategic conjunction with other recruitment efforts across the portfolio of projects it managed, some of which had overlapping recruitment timelines. Website updates were made to the EPM project page on the Smart Columbus website as well as on the Parking Services department website to garner additional potential downloads with visitors already viewing those pages or other information.

12.2.4.8. SHARED

- Toolkit distribution to stakeholders
  - Sample social media copy, images, on-pager, signage, newsletter copy, talking points and frequently asked questions
- Signage at parking garages (30)
- Organic social media posts through project partners and interested community stakeholders
  - Experience Columbus
    - 2 Facebook posts (100,000 followers)
    - 5 Instagram story-slides share (7,000 impressions)
  - Downtown SIDs
    - 1 Facebook post (330 followers)
    - 1 newsletter send (1,850 subscribers)
  - Center of Science and Industry (COSI)
    - 29,000 followers – Twitter share
  - Drive Electric Columbus
    - 340 followers – Twitter share
  - Downtown Columbus
    - 3,170 followers – Instagram share
  - Columbus Commons
    - 27,100 followers – Instagram share
  - North Market
    - 58,700 followers – Instagram share

Figure 12-12: Parking Meter Signage

Source: City of Columbus

Partners distributed emails through regularly scheduled communications with their subscriber lists. This included:

- Downtown Special Improvement Districts e-newsletter
  - One-time send on February 18, 2021
  - Subscribers: 1,850
- The Short North Alliance “Arch to Arch” e-newsletter
  - Eight sends in February and March 2021
  - Subscribers: 350 Short North businesses
- The Short North Alliance “Fans Page” e-newsletter
  - Eight sends in February and March 2021
  - Subscribers: about 7,000
- Updates in relevant meetings (Downtown Commercial Property Owners, Robinson Park)
- Posts in relevant Facebook groups

- Value-added radio ads from CD 92.9
  - 120 30-sec spots (12/15-12/28)
- IKE Smart City interactive kiosk ads through the Short North Alliance

Best practice is to deploy a variety of tactics and channels to effectively communicate with a large audience, and the EPM project is no different. Public sector initiatives often compete for the attention of community members alongside other important public health and safety messaging as well as private sector marketing messages.

There was success in partnering with trusted messengers and community groups to amplify the messaging. The Short North Alliance, Experience Columbus and Downtown Special Improvement Districts were able to put the messaging in front of thousands of eyes that could have either been learning about the EPM project for the first time or been exposed in another communication with this email or social media message being a reinforcing reminder that could finally convert someone who had not yet downloaded the app.

Figure 12-13: Parking Garage Signage

Source: City of Columbus

Toolkit distribution served to be fruitful, but for widest reach it was not enough to share with just one leader at an organization given busy schedules and competing priorities. The communications team went straight to the source, direct messaging community organizations from the Smart Columbus social media platforms to theirs. This allowed the social media managers to immediately bring the content into their content decision making processes. This shorter path garnered more shares and substantively more views than when the toolkit was first distributed.

Additionally, on-site communications worked well to augment digital communications. By adding callouts on parking meters and in parking garages, the communications team successfully met the intended potential users where they were most likely to be or where they may already be experiencing a parking frustration that the EPM project might help avoid in the future. That said, the communications team encountered branding rule challenges where some garages and community partners required just their logo or coloring used in any posters or materials physically placed in their space. It was important in those instances to strongly emphasize the visual of the app that the potential users would see in their app store to avoid confusion.

It is recommended when communities undertake similar projects that they consider what other initiatives they want concurrent community participation. The EPM communications team successfully navigated promotion of the EPM project alongside another Smart Columbus project, Multimodal Trip Planning Application (MMTPA), but it was important to orchestrate a thoughtful and coordinated effort to avoid community confusion and inadvertently cannibalizing performance of other initiatives for which community support and engagement is sought. **Figure 12-14** shows the timeframe for execution of EPM communications activities.

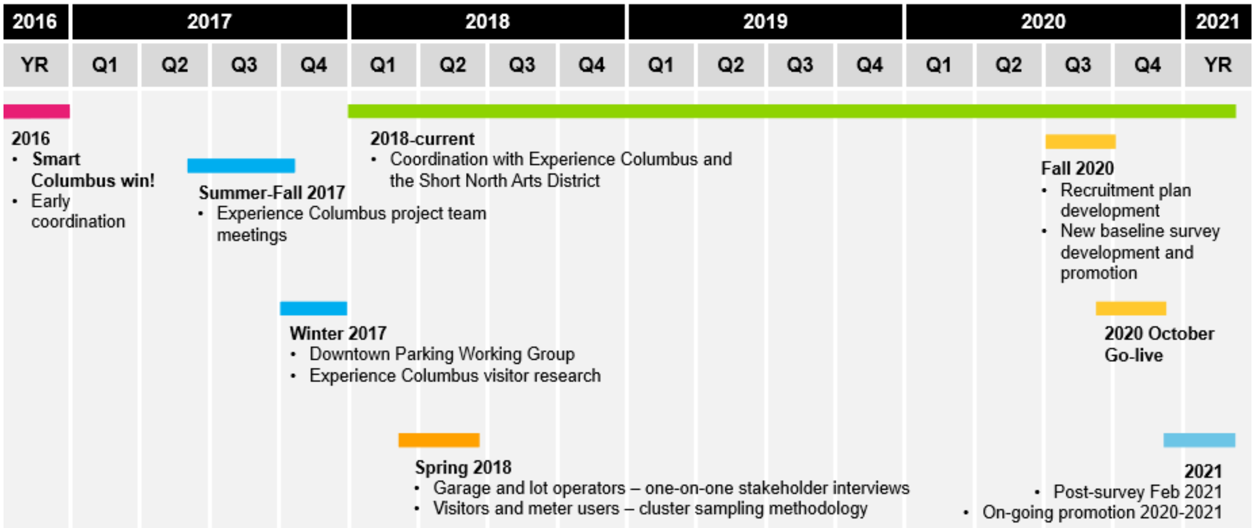


Figure 12-14: Event Parking Management Communications Timeframe

Source: City of Columbus

12.2.4.9. SURVEY

The target audience of the survey was the potential user market for a Downtown/Short North parking app, consisting of adults who drive at least occasionally to the project area from elsewhere in central Ohio. The survey targeted only that sub-population, not the general population of central Ohio. The survey was conducted with a sample recruited online using advertising on Facebook and Instagram and supplemented by an invitation emailed to a subsample of ParkMobile users, all coupled with $10 incentives to attract people to the survey link.

It is important to understand that this was *not* a random sample survey. Results therefore apply to only the target market of adults who travel by car to the Short North or Downtown Columbus and cannot be generalized to the general population of the greater Columbus or central Ohio area. Other sampling and data collection methods had been considered. These included random sampling by mail or phone and in-person intercept surveys. Ultimately none of those were selected because they were either too costly (phone and mail) for the limited budget, too slow (mail), or unfeasible due to COVID (in-person intercept).

The final sample combines responses from two separate sources: (1) a social media survey with a minimum sample of 225 respondents which serves as the basic sample, and (2) a survey of a random sample of 75 ParkMobile app users. The basic sample was recruited primarily via advertising on social media, specifically Facebook and Instagram. The ParkMobile component supplemented the basic social media sample by sending emails to a random sample of ParkMobile customers in targeted Columbus area zip codes. The number of participants was identified in part based on the available incentive funds.

There are advantages to this dual-source sampling. The approach adds to the power of the survey because it enables a comparison of a group of people known to have downloaded the ParkMobile app (and therefore to have access to the ParkColumbus app) with a sample of the general public drawn from social media, whose exposure to ParkColumbus is not known in advance. This comparison can assist in better understanding the demographics and other characteristics of those who were using ParkColumbus before the upgrade with those who were not.

12.2.5. Project Costs

Table 12-3 and the pie charts below show the breakdown of project costs for deployment and operations, as well as costs for specific vendors. Deployment covers the time from the beginning of the project until the soft launch on October 28, 2020. Operations covers from the soft launch until the end of the demonstration.

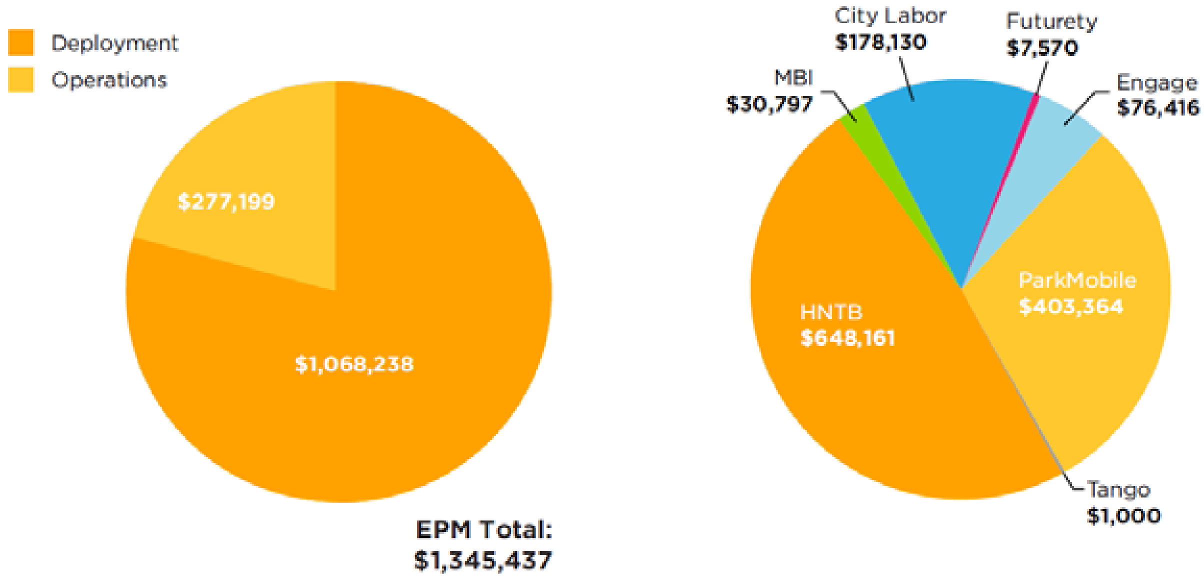


Table 65: Deployment and Operations Costs for the Event Parking Management Project

EPM Vendor Actuals	Deployment	Operations	TOTAL
ParkMobile	$303,364	$100,000	$403,364
Tango	-	$1,000	$1,000
HNTB	$542,344	$105,817	$648,161
Michael Baker International (MBI)	$20,961	$9,836	$30,797
City Labor	$157,213	$20,916	$178,130
Futurety	$7,570	-	$7,570
Engage	$36,786	$39,630	$76,416
Total	**$1,068,238**	**$277,199**	**$1,345,437**

Source: City of Columbus

Table 12-4 shows the expected costs to continue operating ParkColumbus after the Cooperative Agreement concludes on May 31, 2021.

Table 66: Event Parking Management Ongoing Operations and Maintenance Cost Estimate

Description	Cost	Responsible Party	Comments
ParkColumbus Operation Fees	$0	ParkMobile	There will be no ongoing costs to the City, as ParkMobile is funded through traveler paid transaction fees
Predictive availability model – Continue re-training on current data[116]	$400/mo.	City of Columbus	This would include everything as it exists currently (application programming interface (API), and nightly re-training with new data)
Ÿ Support options Ÿ Continued maintenance Ÿ Support inquiries Ÿ Data reporting analytics Ÿ Admin training curriculum	$0	ParkMobile	All operations and maintenance costs will be covered by ParkMobile through the traveler paid transaction fees

Source: City of Columbus

12.2.6. Project Stakeholders

As with the other Smart Columbus projects, EPM was led by the City, with vendor support playing a critical role in implementation. Vendors were primarily responsible for planning, documentation, testing and integration and delivery of system functionality. For EPM, these vendors and their roles are summarized in **Table 9-6**, subcontractors are in parentheses.

Table 67: Event Parking Management Project Vendor Responsibilities

Vendor	Role/Responsibility
ParkMobile	Mobile and web app development, securing Memoranda of Understanding (MOUs) and agreements and parking operators
HNTB	Project management and development of systems engineering and Cooperative Agreement deliverables
MBI	Testing support
Engage (CJI Research)	Outreach and engagement
Futurety	Recruiting and end-user adoption
Accenture	Development of predictive availability model
Tango Card Inc.	Gift cards for survey incentives

[116] *The addition of a new dataset would require the time of a data scientist to evaluate the data, experiment with modifying the predictive availability model, test and/or modify it. The estimated rate for a data scientist is $200/hr. (depending on the individual and the hiring firm).*

Source: City of Columbus

While the project team worked throughout the Cooperative Agreement to develop, deliver, operate, and maintain the EPM project, stakeholders played a critical role in the EPM project. **Table 7-11** summarizes the specific stakeholders that were engaged, as there were many diverse groups that came together to make the project successful. This table highlights their contributions, indicating which project phases each was involved in:

- **Systems Engineering –** these organizations/groups contributed to defining end user needs, ConOps) or SyRS documentation.
- **Development –** these organizations/groups contributed to the build out of the project, including installation, integration, testing, and recruitment/outreach planning.
- **Demonstration –** these organizations/groups contributed to the operations and maintenance of the project from go-live to end of the demonstration.

Table 68: Project Stakeholders

Stakeholder	Systems Engineering	Development	Demonstration
Government			
United States Department of Transportation (USDOT)	X	X	X
City of Columbus Department of Public Service	X	X	X
Community Partners			
Experience Columbus	X	X	X
Short North Alliance	X		X
Downtown Special Improvement District			X
Parking Operators			
Allpro Parking	X	X	X
CampusParc	X	X	X
Citrin	X	X	X
Columbus Convention Center	X		
LAZ Parking	X	X	X
Park Place	X	X	X
Professional Parking	X	X	X
SP+	X	X	X
Towne Park	X	X	X
NRI (Nationwide Realty Inc.)	X	X	X
Parking Technology Providers			
Conduent	X		
IPS Group	X		

Source: City of Columbus

12.3. PROJECT EVOLUTION

Overall, the execution of this project aligned closely with the original approach established at the beginning of the Smart City Challenge. One change, discussed above, is that during the Smart City Challenge application process, the Smart Columbus Program defined three parking projects: EPM, DZA and EPP. DZA and EPP were later removed from the program and portions of those projects were merged into EPM (loading zone information from DZA) or taken on by Parking Services through other projects (EPP).

The scope of changes to the project since the concept was formed are summarized below.

12.3.1. Changes

Most technology projects evolve from concept to development and are updated or refined through use over time. The EPM project was no exception. This section highlights some of the major changes that took place after the concept was defined.

12.3.1.1. SCOPE

12.3.1.1.1 Vendor Selection

During the time that passed from the project concept to procurement, Parking Services had introduced a new project focusing on pay-by-cell for on-street meters and mobile pay only zones within permit parking areas in the Short North. Parking Services selected a vendor team that included ParkMobile as a subcontractor for mobile payment. ParkMobile proceeded to create a white label mobile payment app (mirroring the ParkMobile backend system) called ParkColumbus as a result of the project.

Figure 12-15: ParkColumbus Mobile Payment Signage

Source: City of Columbus

The EPM team had already consulted with approximately 22 parking technology vendors to determine the current market and the technical abilities available. Parking Services requested the EPM project team have another meeting with ParkMobile to understand what ParkMobile had already produced for Parking Services and what features were on the company's roadmap. It was clear after that meeting that the ParkColumbus solution already had a majority of the user needs functionality necessary for the project. The EPM project team conducted a final, detailed review of requirements with ParkMobile, and it was determined that the ParkColumbus solution could meet the needs of the EPM project, and the City of Columbus could have one app for all parking information.

12.3.1.1.2 Parking Prediction Model

Early in project development, the program management office (PMO) spent a lot of time researching, interviewing companies, and participating in demonstrations of products that predict parking availability. From on-street sensors to overhead cameras and even probe vehicle data, there were several innovative technology solutions evaluated. The analysis for predicting availability came down to cost, time involved, ability to provide open data, and the realization that only a data feed was needed, not an entire package or suite of solutions. The team determined that the prediction model could be built better and faster with an open-source code that can be shared with others if the project was kept in-house with the SCOS project team.

To create the model, the SCOS team used historical parking data already available to Parking Services through existing contracts. Datasets included parking meter locations and their alignment with the ParkColumbus zones, transaction data from IPS Group showing payments at the meters and transaction data from ParkMobile showing payments on the ParkColumbus app. The model's algorithm also integrates data from the in-ground parking sensors from the pilot program previously discussed. The model retrains nightly based on new data. Refer to **Chapter 6** for additional information on the model.

Combined Payment System (CPS) – CPS was the payment piece of MMTPA. To continue the concept of creating a holistic smart city, CPS was planned to integrate into EPM as a payment option as well. The CPS project was removed from the Smart Columbus Program portfolio and therefore it was removed from integrating with EPM. Although ParkMobile was working to integrate with CPS as a payment option, the removal of CPS did not hinder the EPM project. ParkMobile already had payment options built in, so no additional development was required to accommodate payments in the app.

Figure 12-16: ParkColumbus App with Parking Prediction

Source: City of Columbus

Requirement changes – With COVID-19 reducing parking demand (and ParkMobile's funding that was dependent on parking revenues), ParkMobile's development resources were significantly reduced. Faced with limited resources, the project team reviewed and updated some requirements to deliver the project within the demonstration period. To ensure the most important system requirements were able to be completed by ParkMobile, a series of requirement assessment meetings took place with members of the project team and ParkMobile. The changes to requirements were thoroughly reviewed by the project team to ensure the original vision of the project was still intact. The focus of the changes was specifying if a requirement should be available on the app, the web, or both, based on historic usage of ParkMobile's app and web. For instance, ParkMobile indicated that 99% of the parking transactions on its platform occurred on the app (versus the web). This led the project team to conclude that identical experiences between the app and web were not critical for on-demand parking (where a traveler searches for and purchases parking on the spot).

Removal of predicted availability for loading zones – Once probe vehicle data was removed as an option and the availability model was not going to include in-ground sensors or cameras to verify occupancy, tracking loading zone availability was no longer feasible. The City is still considering how to collect this data in the future through a curb management initiative planned to kick off in 2021/2022.

12.3.1.2. COST AND SCHEDULE

12.3.1.2.1 COST

This project came in within budget, due in part to reduced scope (removal of CPS) and some functionality discussed in **Section 12.3.1.1** being updated due to COVID-related reduced ParkMobile staffing. The functionality is on ParkMobile's roadmap but was not able to be completed during the demonstration period; therefore, the budget was reduced.

12.3.1.2.2 SCHEDULE

The schedule for EPM was impacted at three points in the project: during the vendor selection process, while assessing COVID-19 related impacts on the parking industry and in the evaluation and creation of the parking prediction model.

The initial delay lasted approximately six months in late 2018 and early 2019 during the procurement process as the project team needed to justify the vendor selection of ParkMobile as a sole source. The PMO preferred to complete a full procurement process for each project and started concept development for EPM by meeting with over 20 parking vendors. During the project's development, but separate from EPM, Parking Services competitively selected and contracted with ParkMobile for the creation of a white label app to allow mobile payment for on-street parking. To ensure the City did not create competing parking apps but did fulfill the concept and user needs of EPM, contracting with ParkMobile with the additional scope of the EPM project requirements based in completing the user needs made sense.

Given that ParkMobile's funding is almost exclusively based on parking revenue, ParkMobile had to stop funding third party developers during the onset of the pandemic, which had an immediate impact on the project. Smart Columbus and ParkMobile spent time understanding the impacts and how the project could still be completed with the internal ParkMobile team. As discussed previously, any services that were not in the updated scope to complete were also removed from the budget.

The project also experienced a schedule delay in releasing the parking prediction functionality due to the evaluation of third-party vendors that provide predictive availability for on-street parking. Significant time was dedicated to evaluating these vendors and ensuring the ultimate solution was truly available to deploy, financially sustainable, and accurate. Once the decision was made to use the SCOS to create the parking prediction model, there was a brief delay to evaluate which time period of parking data should be used. Given COVID-19's immediate negative impact on parking, using any longer-term parking data proved inaccurate in predicting availability.

12.3.1.3. STAKEHOLDERS AND PARTNERS

The City of Columbus, Department of Public Service, Division of Parking Services – Parking Services partnered with the PMO throughout the EPM project and is the post-demonstration owner of the system. Its partnership quickly went from attending meetings and giving input to being the most valuable partner of the EPM team. As mentioned earlier, Parking Services took over execution of the goals of EPP and DZA, allowing the EPM team to place all efforts on EPM execution. Separately, when outside vendors were unable to meet the requirements of EPM for predictive analytics, Parking Services assisted with identifying datasets that could be used to build the parking prediction model and participated in test plan development and execution to ensure EPM could use the prediction model for project success.

The Short North Alliance (SNA) – SNA is a non-profit organization serving the businesses and property owners in the Short North and surrounding areas. The SNA aided in sharing information on parking topics in the Short North from a business or property owner's perspective during the concept phase. At the time of the public launch, the SNA increased its roles in the project by assisting with marketing the EPM project to its constituency, including adding EPM information to newsletters and adding EPM advertisements to kiosks located in the Short North.

12.3.2. Challenges

12.3.2.1. GLOBAL PANDEMIC

The most significant challenge that impacted this project was the COVID-19 pandemic. Its effect on transportation and parking was swift, unexpected, and uncontrollable. On March 22, 2020 when the Governor's Executive Order called for many downtown workers to work from home, the need for parking in the project's geographic area was greatly reduced. In the first week alone, on-street parking revenue dropped 63%, and fell another 44% the following week.

Figure 12-17: Parking Meters

Source: City of Columbus

This had an immediate effect on ParkMobile's business model as its primary revenue source is parking transaction fees. The pandemic's adverse effect on parking demand severely affected ParkMobile to the point where a reassessment of what system requirements could be achieved had to take place. The EPM team and vendor prioritized functionalities that would be the most advantageous to the traveler and would still allow for the project to collect data. The project team also expanded the schedule of release dates to allow for ParkMobile's smaller team to maximize the functionalities it could deliver. Only during the last month of the demonstration did Downtown and Short North parking start to see a modest recovery due to the Governor's decision to allow bars and restaurants to stay open later and permit a limited number of fans at sporting events. While there were challenges from the pandemic, the encouragement of contactless payment to reduce the risk of exposure saw an increase in credit card and app usage. Overall, adoption of the app has grown from 24% of all transactions pre-COVID to roughly 45% of all transactions.

12.3.2.2. DATA COLLECTION

Given the pandemic's effect on the use of on- and off-street parking, collecting data for EPM has been a challenge. Valuable data have been collected but nowhere near the quantity that would have been collected without COVID-19.

12.3.2.3. ON-STREET PARKING PREDICTION

The EPM project was always envisioned to include parking prediction for on-street parking. The EPM project team interviewed many vendors who shared their predictive analytics ability, including the ability to use probe vehicles to sense open and occupied parking spaces, but the solutions were not feasible for this project because they were either too expensive, too infrastructure heavy (i.e., cameras), limited in data availability without commitment to a larger package, or were not ready for deployment. Fortunately, the interviews conducted enabled the team to recognize that the experience of the SCOS project team could be used for a predictive analytics tool that could be developed quickly and used for the EPM project using the data that the City of Columbus already had in its possession. This open-source tool is now being used for the EPM project and is also available for others to use on Github.[117]

12.3.2.4. ACCEPTANCE OF USING AN EXISTING PARKING APP PROVIDER

While the guidance in the Smart City Challenge strongly encouraged and expressed a preference for open-source solutions, the EPM project was an example where customizing a commercial off-the-shelf product was more efficient and sustainable for the City. Parking Services had already contracted with a vendor team that included ParkMobile to enhance the parking experience, and the product included many of the desired requirements. To create a competing, open-source product would have been inefficient, time-consuming, wasteful of the resources available, and confusing to the traveler. To justify the change in approach, the EPM team developed justification documentation for USDOT to approve the EPM project to move forward with ParkMobile. Ultimately, the justification document was not necessary as the USDOT changed the subcontracting approval requirements and the City advanced development of the application enhancements in the ParkMobile application.

12.4. CONCLUSIONS, LESSONS LEARNED AND RECOMMENDATIONS

The EPM project intended to address the following service gaps:

- The absence of one location to share on-street and off-street parking opportunities
- The lack of a comprehensive platform to plan, book, and pay for parking (on-street and off-street)
- Loading zone information was mainly available on street signage and not in advance
- Travelers looking for on-street parking would drive around in circles until a spot opens up given the lack of on-street availability prediction

[117] *The Parking Prediction Model is available at https://github.com/Datastillery/parking_prediction. The Parking Prediction Model Data Transformation can be found at https://github.com/Datastillery/parking_prediction_orchestration.*

THE CITY OF COLUMBUS ANDREW J. GINTHER, MAYOR

The EPM project addressed these gaps in service identified in the project ConOps. In working with parking operators to partner in the EPM project, the City solidified its relationships and the goal of all team members to create easy to access parking and more opportunities to showcase all the parking available.

In working with parking operators to bring parking facilities onto the ParkColumbus platform, the idea was overwhelmingly supported to be able to share all Columbus parking information on one platform. The parking operators were always willing to come to the table and talk through their business needs, discuss concerns about data collection given they are in a competitive business, and make equipment changes as necessary to be part of the project.

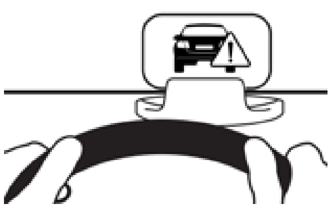
Traveler needs were sought through user needs surveys for development of the ConOps and helped develop the service gaps and guide the ultimate solution. When parking needs resume, ParkColumbus will be ready to assist with planning, booking, and paying for parking.

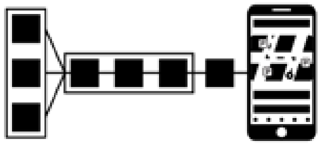
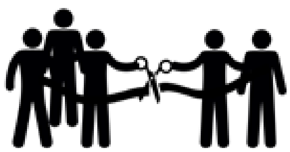
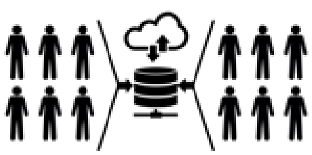
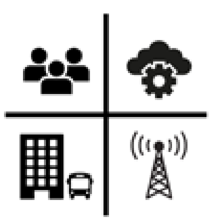
> During the last survey, 91% of the respondents stated post-COVID-19, ParkColumbus would be useful to them when making a trip downtown or to the Short North.

12.4.1. Smart City Vision

The EPM project addressed City challenges and met the original expectations defined in the City's Smart City vision. The project addressed transportation challenges by deploying applications and strategies in the following USDOT's Vision Elements in **Table 12-7**.

Table 69: Event Parking Management Project Relationship to USDOT Vision Elements

VISION ELEMENT #3 Intelligent, Sensor-based Infrastructure 	The vehicle sensor pilot funded and managed by Parking Services incorporated intelligent sensors built into the road to show real-time parking availability at on-street metered spaces. The data were added to the predictive availability model and overrides the prediction methodology to give real-time availability. While the sensors were part of a now-completed pilot, they remain in place and continue to send data to the City for parking analysis and to the SCOS for use in the parking prediction model for ParkColumbus and for the public.
VISION ELEMENT #4 User-focused Mobility Services and Choices 	The EPM project deployed a website and mobile app focused on user needs around parking from both the customer and parking operator's perspective. These informational parking portals also allow users to quickly locate ADA or EV charging stations around their destination by filtering for those parking options.

VISION ELEMENT #5 Urban Analytics 	The EPM project's predictive availability model uses data from parking meter cash and credit card payments (both at the meter and from mobile payment transaction data) to predict future conditions (availability) of on-street parking. Real-time data from in-ground sensors are used to overwrite the predictions for those zones with sensors before it is transferred to ParkMobile for display in ParkColumbus. The parking meter usage data is collected by IPS Group and ParkMobile on behalf of the City of Columbus.
VISION ELEMENT #7 Strategic Business Models and Partnering 	The EPM project, by entering a creative and strategic partnership with Experience Columbus and the parking operators, enabled a low-cost solution for the City. Experience Columbus gave its time to convene City representatives and parking operators to discuss the concept of EPM, hold regular updates and eventually help market the EPM project. The parking operators participated in the EPM concept development and data sharing, executed contracts with ParkMobile to participate in ParkColumbus, and paid for updated technology and gate arm equipment to accommodate EPM needs.
VISION ELEMENT #9 Connected, Involved Citizens 	The EPM project conducted an outreach strategy to promote ParkColumbus and the software solution's ability to more effectively locate available parking on the go or in advance, informing the traveler of increased efficiency to mobility. Fortunately, the outreach effort to connect more travelers was extended with help of local campaigns from parking operators, community and business groups and Experience Columbus. This help proactively engaged various traveler segments, i.e. tourists with Experience Columbus and business owners and their staff with the business group, Short North Alliance.
VISION ELEMENT #10 Architecture and Standards 	The EPM project abided by the current architecture, standards and tools of the industry by using Architecture Reference for Cooperative and Intelligent Transportation (ARC-IT), Systems Engineering Tool for Information Technology (SET-IT) and published Intelligent Transportation Systems (ITS) standards to document the project's capabilities in the Smart Columbus System Architecture and Standards Plan (SASP). In this way, the EPM project is contributing back to the ITS community by creating a replicable architecture that can be reviewed/leveraged by other cities and that will make it more interoperable as other similar projects are deployed in the City, state and region. EPM in particular benefited from the version updates in the available tools that were released twice during the project, as more parking-related service packages were released that aligned with the project's architecture, reducing the customization in the objects, interfaces and information flows it contained.

Source: City of Columbus

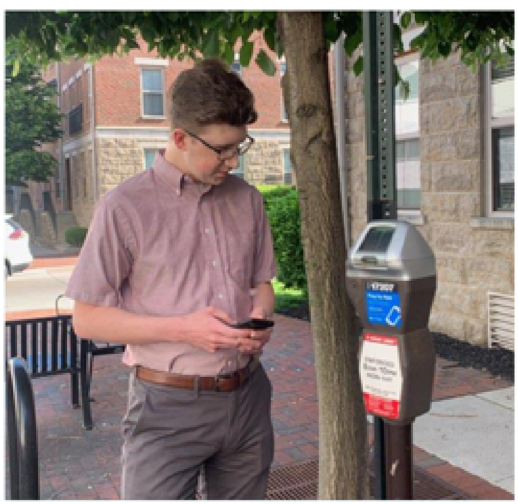
12.4.2. Conclusions

A central goal of the EPM project was creating a “one-stop shop” for all things parking. Travelers needed one place to locate all parking options, on-street and off-street, in the Downtown and Short North to reduce parking frustration. While the original concept had focused on parking needs around events, the use case for parking information was easily expanded to everyday parking both on-street and off-street. The EPM project developed a one-stop shop functionality within the ParkColumbus mobile app and web portal. This forward-thinking parking solution is positioning the City well as Parking Services continues to evaluate solutions around parking and traffic management. Parking Services has a procurement underway for curb management and the data from the EPM project will be key in showing how parking impacts curb space in Columbus. City government, unlike state or federal, relies on developed relationships with local businesses like parking operators. The EPM project brought parking operators from downtown and the Short North together to focus on a similar goal and solidified those relationships for the City which will be fundamental for parking recovery.

12.4.2.1. IMPACT TO RESIDENTS

While the project couldn’t be tested from the public’s perspective on a large scale given the lack of parking used due to the pandemic, a January through March 2021 survey led by ParkMobile rated the ParkColumbus app with 4 stars. ParkMobile also shared that the ParkColumbus transactional ranking went from number 21 to number eight when comparing cities that it works with for the first quarter of 2020[118] versus the first quarter of 2021[119].

User challenges such as not knowing if any on-street parking will be available, if a loading zone is a valet zone at night, or what is the best price to pay for parking in a garage have all been overcome due to the EPM project. The EPM project sought to identify and then focus development of the parking solution around real traveler user needs which is vital to future user adoption.



Downtown Young Professional Uses ParkColumbus for Work and Play

Robert is a young professional that works in Downtown Columbus. He prefers to ride the bus or bike to work but depending on the weather or his work that day, he sometimes opts to drive. He uses ParkColumbus to find a long-term parking spot during his work day. Robert lives in Merion Village, south of Downtown, but finds himself in the Downtown or Short North a lot. **“When I’m headed to the Short North for dinner or drinks, I check the on-street parking availability to see how busy it is to decide if I attempt to find a spot or head to a garage or further out parking spot directly. My partner and I are avid Columbus Blue Jacket fans and now that games have started up again, I can use ParkColumbus to reserve a spot in advance so I’m not stranded by the bus after hours or paying surge pricing for a ride-hail home.”**

Robert, ParkColumbus User, Merion Village

[118] *First quarter 2020 – 187,940 transactions*

[119] *First quarter 2021 – 333,658 transactions*

12.4.3. Lessons Learned

12.4.3.1. AGILE DEVELOPMENT

The systems engineering process and documentation have longstanding, well-recognized value. For this technology-based project, following the traditional systems engineering methodology was challenging given that technology and public expectation move quickly. The project was intentionally switched to Agile development from the V-Model approach after system requirements were completed to create an efficient and ongoing release of required features to the public. This switch was the team's solution for meeting systems engineering documentation requirements while getting the project out to the public in the most efficient manner. A streamlined version of systems engineering is recommended for projects based purely in technology to ensure the product gets to the public faster. Starting with an approach grounded in the ability to iterate concept and development while having continual traceability and check-ins would have sped up the project.

12.4.3.2. TECHNOLOGY

Technology was key to this project and the project team interviewed over 20 parking technology vendors about their solutions as the EPM concept was being developed. The team found that as the project turned to development, specifically around the predictive analytics, many technology companies could share their vision but not a live, ready to be tested solution. The lesson learned was to ask up front whether the technology is production-ready, and if so where it was already in use. Understanding the technology terminology is also critical in understanding the difference between a live product and a product concept. Other technology lessons learned include getting a reliable cost for a product early on, as in many cases new technology can be cost-prohibitive and quickly outdated. More importantly, look internally – often the right expertise and data to deliver a solution is already available. The EPM team worked with the SCOS team to create a solution when the market could only produce concepts and cost-prohibitive solutions. This internal solution was less expensive, allowed for the creation of shareable, open-source code, and allowed better collaboration with Parking Services for desired customizations.

12.4.3.3. LEVERAGING EXISTING CONTRACTS

The EPM project leveraged two existing contracts to make the project a success. First, the team chose ParkMobile due to its ability to successfully implement the needs of the EPM project and because it was already under contract with Parking Services. This created efficiencies in procurement and relationships because part of the EPM team was already working with ParkMobile. This also created a built-in user base with the users being amassed for ParkColumbus. Second, the team chose to create the parking prediction model in-house within the contract for the SCOS team. Similar models were not ready to be tested or were cost-prohibitive and were not going to be available as open source.

12.4.3.4. VENDOR SELECTION

Selecting the right vendor and the right process made this project seamless. ParkMobile's future vision and short- and long-term roadmaps for functionality aligned with the EPM project. The EPM team researched many existing parking apps, but no one provider could provide every piece of the puzzle. Some companies could provide data but not payment abilities, and others lacked accurate data. After this research was conducted, Parking Services moved forward with the Short North Parking Plan, which required an RFP for mobile payment for on-street parking. ParkMobile was selected for that project. The EPM team realized ParkMobile could build on the existing Parking Services app, ParkColumbus, and create a website to meet the EPM project needs. After much due diligence and given that ParkMobile was currently under contract with the City, the team decided against creating a competing app that would not be sustained. It did not make good business sense to select another application for this demonstration given the City's existing use of ParkColumbus.

Another advantage of selecting ParkMobile was that it had a built-in sales team to recruit parking providers to join the ParkColumbus platform. ParkMobile has experts in the parking industry, and many of the Downtown and Short North parking operators had already joined in the overall ParkMobile platform. To join ParkColumbus, the parking operators had to simply sign an MOU to share data with the SCOS to ensure performance measurements could be reviewed.

Technology vendors are often leery of creating a customized product that meets the needs of only one customer. ParkMobile offered use of the base ParkColumbus product for the EPM project. The base application did not meet all of the EPM user needs and requirements and would not have met the satisfaction of the PMO. Those user needs and requirements would have been placed on ParkMobile's roadmap to be addressed when it made sense from a business perspective. In order to have EPM user needs and system requirements met, contract requirements were negotiated. The City of Columbus had to be sure the defined needs and requirements were met within the ParkColumbus app. ParkMobile wanted to ensure that any changes would not have a negative effect on its broader base of users and wanted to ensure consistency on all its platforms.

12.4.4. Recommendations

For agencies considering the deployment of a consolidated parking app or website, the EPM project team has the following recommendations:

- **Leverage existing contracts –** A major contributor to the success of the EPM project was the use of existing contracts. The City of Columbus had an existing, competitively selected vendor contract with the final solution provider that allowed the team to jumpstart development, relationships, and familiarity of the product. The City also had an existing contract with the developer of the parking prediction model and the parking data providers. Beyond the contractual and people relationships, consider bringing on other teams and vendors who may be involved in the project during scope development and implementation to ensure the team is aware of all connections, and efficiencies are identified.
- **Choose a team wisely –** Good partners and team members were critical to the success of the EPM project. The team and outside partners assembled for EPM included people passionate about moving parking forward with advanced technology. These included:
    - Parking Operators
    - Experience Columbus
    - Downtown SID
    - Short North Alliance

  Having this team allowed for support at every turn, from understanding user needs from Experience Columbus surveys and direct conversations with parking operators, to marketing with the Downtown SID and the Short North Alliance.
- **Have a project champion –** Robert Ferrin as the Department of Public Service Assistant Director for Parking Services was the EPM project champion. Robert brought his ten years of parking experience, his passion, and the resources of his full parking team to ensure this project's success. Having his leadership and support was imperative to keep the project aligned with the City's broader parking efforts to create seamless integration and communications to the public and parking operators.

- **Ensure the technology is available –** Interview technology companies to understand the extent of their product's capabilities. Technology continues to move at a fast pace, especially concepts. Be sure to ask technology companies if their product is currently available or is in the concept phase.
- **Custom off the shelf (COTS) versus in-house development –** While it was valuable to research COTS products for probe vehicle and other parking availability data, the idea of looking internally did not happen until the team realized the high cost to purchase data and the lack of readily available solutions (probe vehicle data). The internal review of data allowed the team to realize that what was already available in-house was just as valuable as what was being described from the vendors. The in-house development of the predictive availability model was less expensive and produced an open-source product for others to use.
- **Broaden the definition of "team" –** Often project teams just include the project owner and those responsible for delivering the project. For the EPM project, the definition of team was broadened to ensure that many voices were heard and those with special expertise could share user needs. For example, the parking operators were an end user of the EPM solution, and they were at the table with the rest of the project team sharing their needs to ensure they were included in the user needs. The Short North Alliance and Experience Columbus, representing Short North businesses and tourism respectively, were both at the table sharing input from their constituents to ensure the PMO understood the parking needs of employees and travelers in the area. Having this broader definition of team also allowed for complete transparency around the project and helped with recruiting users once the project launched. The transparency was important because the PMO needed data from each project to track performance as part of the Cooperative Agreement. The parking operators were able to give input into the data to be collected for the project, so when the parking operators were presented with an MOU to share data, there were no surprises.

12.5. SUMMARY

The EPM project addressed Columbus' parking challenges presented in the City's Smart City vision with great success and sustainability and was an excellent example of how a regional vision could be achieved by leveraging an existing application and vendor. While the EPM team developed the systems engineering documents independently, in the end, building on an existing solution and relationships, enabled the creation of a dependable, forward thinking team with a strong project champion. Even the unanticipated challenge of COVID-19 and its effect on the need for parking were not enough to stop the EPM project from being successful. The project team continued working with the dedicated stakeholders through development and testing to ensure the product is ready for travelers when parking needs come back. Alignment of the EPM project with the ongoing Parking Services project ensured sustainability, eliminated duplication of work and reduced project costs. Parking Services will sustain the EPM project and continue to generate data for the City's and the public's use.

Chapter 13. Connected, Electric, Autonomous Vehicles

13.1. PROJECT OVERVIEW

The City of Columbus was able to demonstrate two Connected Electric Autonomous Vehicle (CEAV) deployments through the Smart City Challenge (SCC) program. As part of the SCC, the CEAV project sought to demonstrate urban automation, one of the 12 USDOT Vision Elements, as well as several other elements. The original proposal in the award application envisioned multiple routes in the Easton area of Columbus, connecting existing transit routes to jobs and businesses. However, the technology at the time of deployment was not capable of navigating the challenges of these routes. Therefore, the City worked with partners and stakeholders to determine new routes to serve the public during the demonstration period that are described in this section.

The first CEAV deployment was along the Scioto Mile in downtown Columbus, serving such area attractions and cultural resources as the Center of Science and Industry (COSI), Veteran's Memorial and the Smart Columbus Experience Center. This service operated from December 2018 until September 2019. The second CEAV deployment served as a first mile/last mile (FMLM) connection to transit in Linden, an opportunity neighborhood in Columbus. This service launched February 2020 and operated for about two weeks until an on-board incident paused passenger operations. Ultimately, the COVID-19 pandemic impacted the ability to return to passenger service, and the City reimagined the mission of the vehicles, launching a food pantry delivery service in July 2020 that concluded in April 2021. Cooperative Agreement regulation 2 CFR §200.313(c)(2) allows the federal government to approve temporary use of grant equipment for non-federally funded programs or projects, provided that such use will not interfere with the work on the projects or program for which the grant equipment was originally acquired. **Figure 13-1** shows the award application routes (left) and the deployed routes during the Smart Columbus demonstration program.

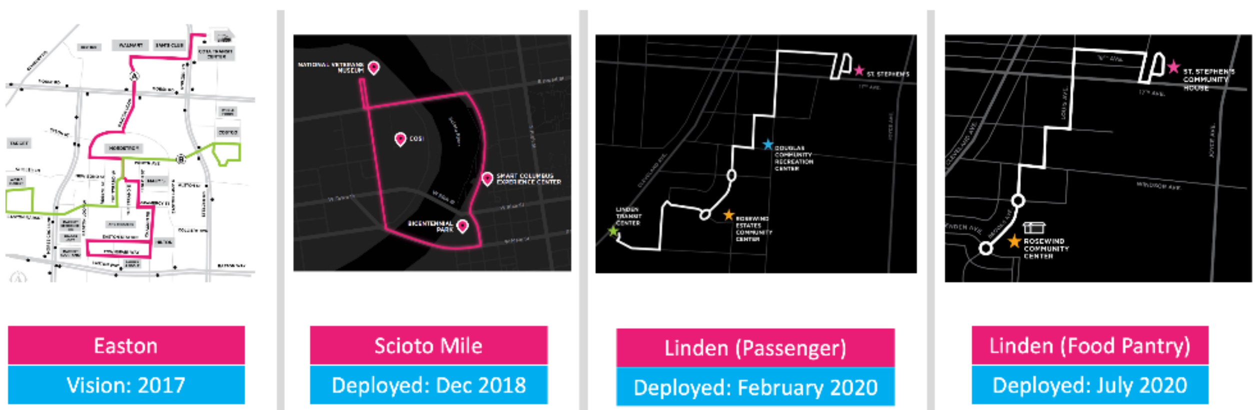


Figure 13-1: Connected, Electric, Autonomous Vehicles Vision and Deployments

Source: City of Columbus

13.2. DEPLOYMENT SUMMARY

13.2.1. Easton Connector

While developing project documentation such as user needs and required agreements to enable the deployment of the Easton routes included in the SCC application, the project team hosted Vendor Days on February 15-16, 2018, to engage with the technology vendors and determine the current capabilities of automated driving systems. The takeaway from the engagement was that the Easton routes presented significant challenges for automation based on capabilities and the required vehicle capabilities may not be possible until 2020 or later, which did not align with the required timeline for the CEAV project.

One of the routes proposed to connect to COTA's Easton Transit Center, but an operational challenge identified by the vendors included an unprotected left turn from Transit Center Drive onto Stelzer Road, a higher-speed road on which vehicles travel faster than the posted speed limit of 35 mph. If it was proposed to remove this connection, user adoption and system usage could have been limited because there would no longer be a FMLM connection from the transit hub.

Another challenge was a required lane change on Morse Crossing to be able to cross Morse Road. At the time of the workshop, dynamic lane changing was not deployment-ready and was not expected to be until 2019 or later. Finally, where the route was proposed to cross Morse Road, the cross-section was eight lanes wide and presented operational challenges for signal timing along the corridor based on the current travel speeds of the vehicles.

Following identification of these challenges, the City of Columbus developed an alternate proposal for the CEAV project to plan, demonstrate, and evaluate automated vehicles (AVs) in Columbus. This recommendation was submitted to USDOT on April 9, 2018.

13.2.2. Smart Circuit

The first CEAV shuttle route in Ohio traveled along the Scioto Mile in downtown Columbus seven days a week from 6am to 10pm. The intent of the deployment was to develop procurement protocols, document the steps for deployment to aid others in the future, educate residents and visitors about AV technology, and link educational and cultural assets located on the route for residents and visitors. The route, shown in **Figure 13-2**, had four stops: (1) Smart Columbus Experience Center, (2) Bicentennial Park, (3) COSI, and (4) National Veterans Memorial and Museum. The route was an ideal test case due to the low-speed nature of the roads, the low risk of the deployment due to the short length and low volume of most of the roadways, and the low impact to riders if there were route disruptions.

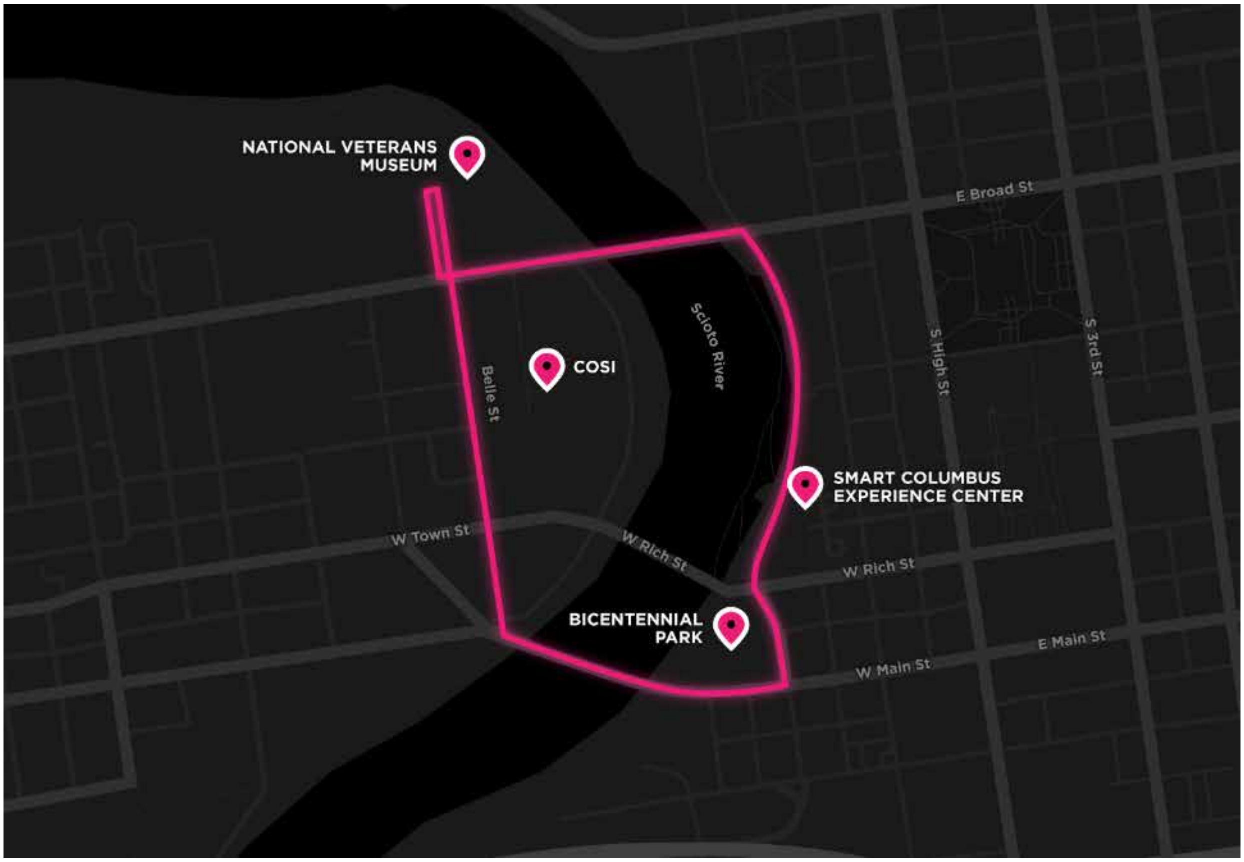


Figure 13-2: Smart Circuit Route Map

Source: City of Columbus

13.2.3. Linden Empowers All People (LEAP)

The second CEAV demonstration in Columbus sought to demonstrate automated vehicle technology in a manner that would fit within the transit ecosystem, specifically addressing access to community services from existing transit routes. In addition, the demonstration would raise awareness and educate the community about the technology and its possibilities. The Linden LEAP provided a FMLM connection in the Linden neighborhood seven days a week from 6am to 8pm. As with Smart Circuit, the intent of the Linden LEAP deployment was to demonstrate AV technology in a real-world application, further refine procurement methods, document the steps for deployment to aid others in the future, educate residents and visitors about the technology, and become a daily modal option. The route, shown in **Figure 13-3**, had four stations: (1) St. Stephen's Community House, (2) Douglas Community Recreation Center, (3) Rosewind Estates, and (4) Linden Transit Center. The route selected was identified through stakeholder input as a solution to a transit gap for visitors and patrons of St. Stephen's Community House, which provides a wide range of community services, including a food pantry, as there is no direct transit access to the site from existing bus routes.

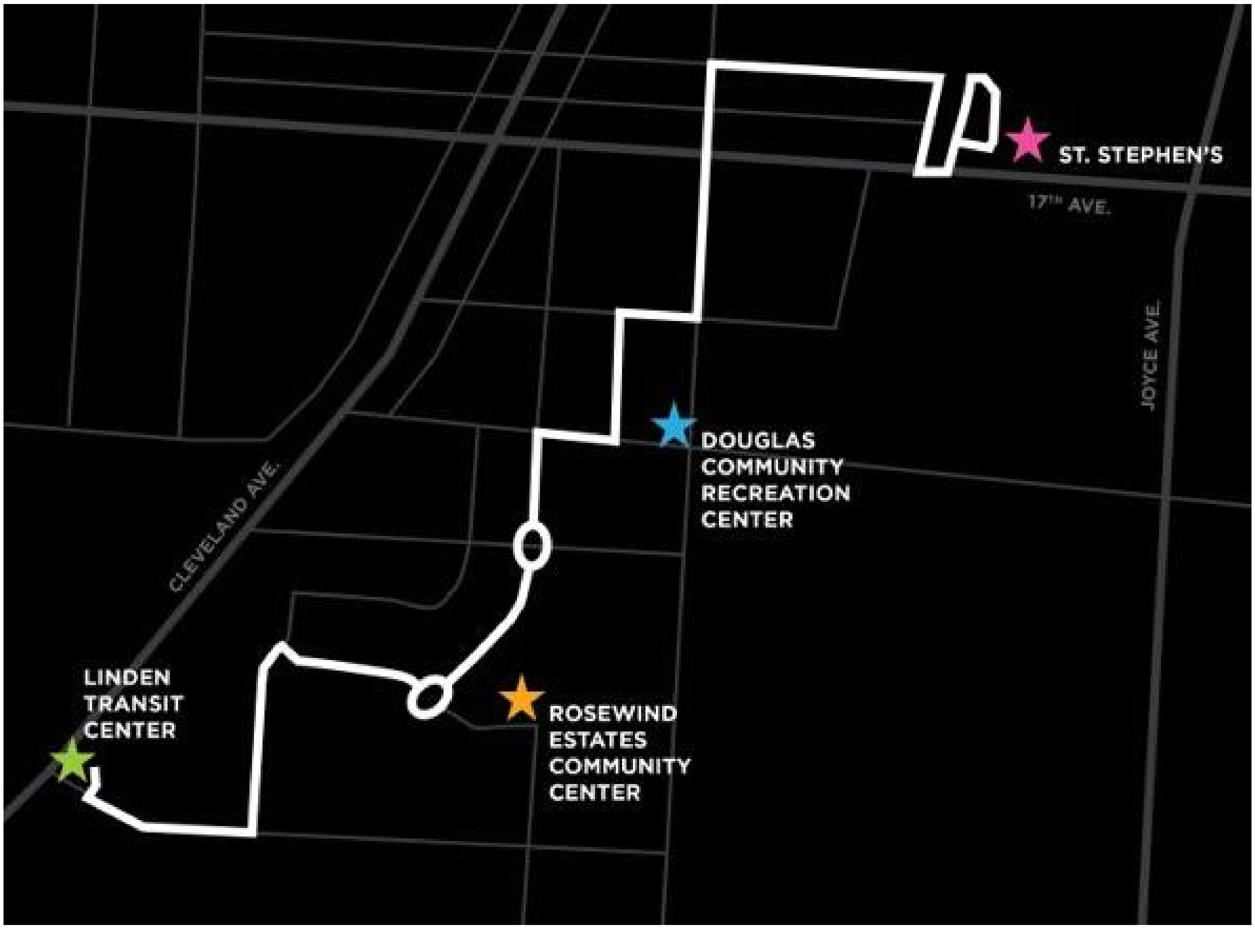


Figure 13-3: Linden LEAP Passenger Service Route Map

Source: City of Columbus

The passenger service launched on February 4, 2020, and operated until February 20, 2020, when an emergency stop resulted in a passenger slipping from her seat. Passenger service was suspended, and the shuttles continued to operate testing and training runs with only project staff onboard to evaluate all potential reasons and factors for the sudden stop. On April 4, 2020, all operations ceased due to the pandemic. Although the National Highway Traffic Safety Administration (NHTSA) approved proposed mitigations for the vehicle vendor, EasyMile, to return to passenger service in May 2020, the persistent global pandemic impacted the ability to implement mitigations following the incident, and also led to new challenges related to passenger service with the importance of social distancing and increased sanitizing procedures. Therefore, the project team worked with their stakeholders to define an alternate service that led to the proposal of the food pantry delivery service, which started on July 30, 2020, to meet some of the goals of the program including increasing access to goods for those that may be food insecure and have transporation difficulties related to returning home from St. Stephen's while carrying a food box. **Figure 13-4** shows the food pantry route.

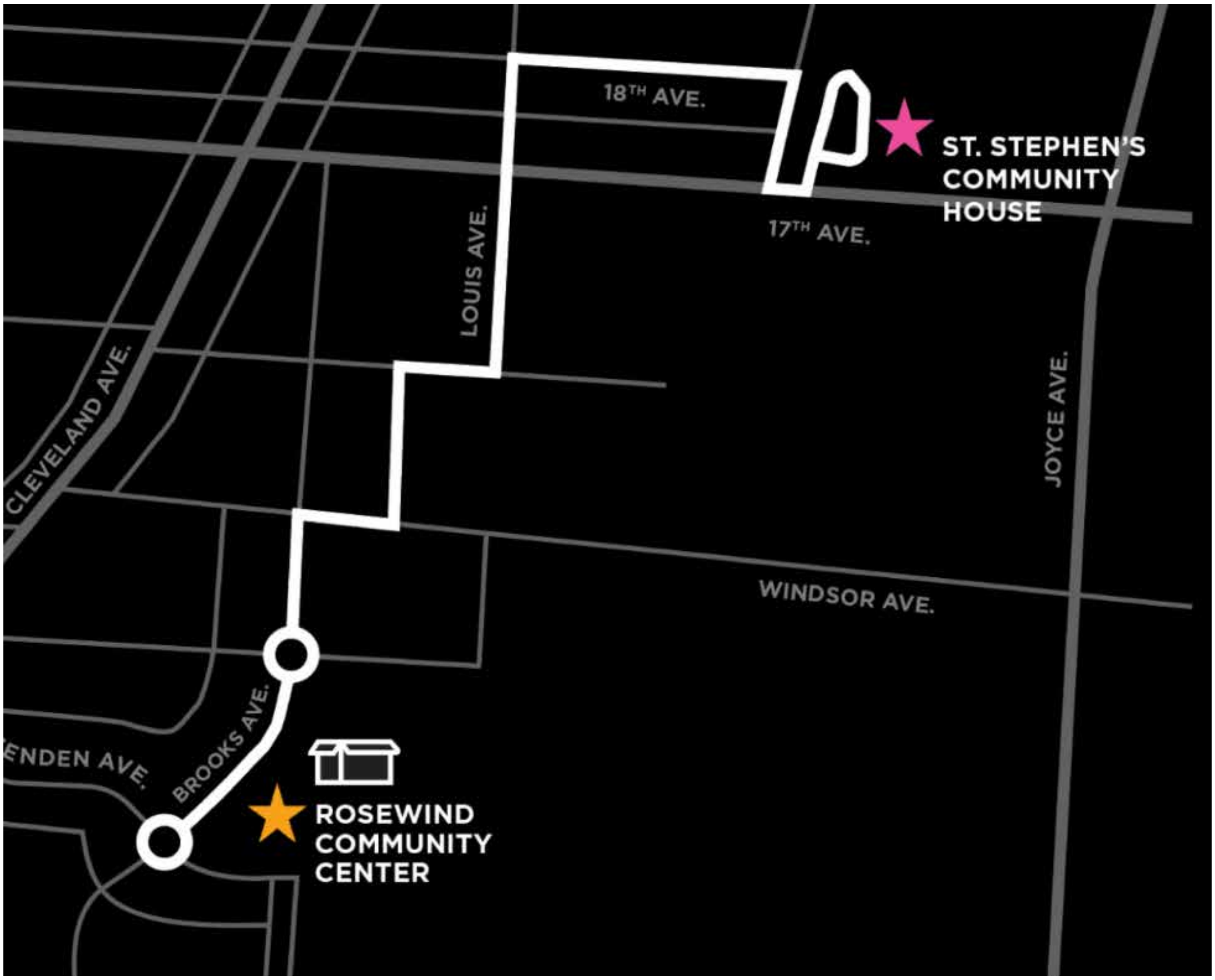


Figure 13-4: Linden LEAP Food Pantry Service Route Map

Source: City of Columbus

13.2.4. Demonstration Vehicles

The vehicles used for the two routes were from different vendors. May Mobility provided vehicles for the Smart Circuit route, and EasyMile shuttles were provided for the Linden LEAP service. Both deployments were required by the contract to have operators on board during service who could manually control the vehicles if needed. The May Mobility vehicle used in the first demonstration was a retrofitted Polaris Gem e6, shown on the left in **Figure 13-5**, capable of accommodating six people in the shuttle including the operator. May Mobility modified the second and third rows of the vehicle to face each other in a “campfire” configuration rather than the factory default “theater” seating. All sensors and equipment were retrofitted into the standard vehicle to accommodate the automated driving system.

For the second demonstration in Linden (both passenger and food pantry), the EasyMile EZ10 Gen3, shown on the right in **Figure 13-5**, was a purpose-built vehicle that EasyMile designed and developed with manufacturing partner Ligier, a leading French specialty vehicle fabricator. The interior of the vehicle has six seats and two leaning bars, in total accommodating 12 passengers seated and standing including the operator. The sensors and controls were included in the vehicle’s original design with no retrofitting necessary to accommodate automation.

Figure 13-5: Smart Circuit (May Mobility) and Linden LEAP (EasyMile) Shuttles

Source: City of Columbus

13.2.5. Systems Engineering Approach

The City began the project using the more traditional V-Model systems engineering approach following the SCC award. While developing the documentation, it was determined that the traditional V-Model process lends itself to defining what an AV should be (designing an AV) rather than focusing on solving a transportation problem by procuring an AV. Given that urban automation was one of the vision elements that the City was attempting to demonstrate, the “solution” of an AV was already determined, and the City wanted to develop a process that other cities could replicate in deploying AVs. In response to this challenge, the City decided to follow a Hybrid approach incorporating traditional systems engineering with a Hybrid delivery approach. These approaches are described in more detail in **Chapter 2**.

The first CEAV deployment, Smart Circuit, was funded and led by The Columbus Partnership and the Ohio Department of Transportation (ODOT) through DriveOhio, a specialty practice contained within ODOT, and used a more Hybrid systems engineering approach to deploying an automated shuttle service. The process began with route definition; the route was set up, tested, refined, tested, and refined again until it operated smoothly. The goal of the deployment was to learn and evaluate procurement for this type of service. Due to the emphasis on demonstrating and showcasing technology in an urban environment, a route that would serve visitors along Columbus’ Scioto Mile was identified, where schedule adherence was less critical and would support lower-speed travel, and requirements were developed to define the service to be procured.

Through this process, the original vision developed in the SCC was still vetted, refined, and modified as appropriate through stakeholder and public input. An Operational Concept (OpCon) was developed instead of a Concept of Operations (ConOps). Although a traditional ConOps is a very valuable tool, in this case, it was better applied to defining the design for the vehicle itself. The OpCon instead allowed the project team to define user needs for the service to be provided by the AV, and how it should be integrated into the community for the benefit of both passengers and agencies through the potentially valuable data the service could generate. As a result of this process, it was recognized that the City of Columbus would be procuring a commercially available off-the-shelf vehicle. The OpCon took into account user needs, high-level requirements, the goals of the project, performance evaluation, and use cases for deployment, but did not include fully developed operational scenarios. The OpCon was used to further define where the second CEAV deployment should be and what purpose it should serve. Once this was completed, to CEAV project effort shifted to procurement, where the Request for Proposal (RFP) contained more detailed requirements for the topics that focused on testing, operations, data, safety, and passengers rather than developing a System Requirements Specifications document.

Prior to launch, each selected vendor’s product had to be tested to verify it was delivered as designed. Within the procurement parameters, testing requirements were identified that the provider needed to meet.

The vendor was responsible for performing a test that would showcase that functionality prior to being permitted to perform passenger service.

For the second CEAV deployment, a test plan was developed by the project team in conjunction with the City's RFP since the Hybrid process did not include the development of a System Requirements Specification document. The testing was conducted in the three phases listed below. These phases also aligned with the phases of the first deployment's testing.

- **Factory Acceptance Testing –** to serve as a factory audit and ensure that there are procedures and protocols in place that support the vision of safety, and to witness the testing of the vehicles before shipment to a deployment site
- **Preliminary Acceptance Testing –** to give the project team the assurance that the vehicles can operate as expected prior to moving the testing onto public streets and in mixed traffic
- **Final Acceptance Testing –** to showcase the vehicles can operate on the actual route as identified in the RFP and that they can safely perform the functions of an automated vehicle

For the Linden LEAP service, the Test Plan included 52 unique tests of the vehicles and vendor processes and procedures. Altogether, 115 tests were completed over the three phases, due to the fact that some tests were duplicative over phases, such as showing how the vehicle departs from the station or deploys the accessibility ramp. This repetitive and thorough testing was key to validating the performance between the closed course and the actual route. To simulate Vulnerable Road Users and other obstacles, the project team acted as pedestrians and used scooters, bicycles, cones (roughly the height of small children), and a rolling basketball. The project team also developed Standard Operating Procedures (SOPs) which were vetted with all community stakeholders including first responders and the vehicle operator prior to launching the service.

Both shuttles had challenges during testing for weather events, particularly during rain and snow. It is not always easy to schedule testing for these events, but when the project team was able to conduct some testing, the sensors and system identified the precipitation as obstacles. The contract documents identified that operations would be suspended during Franklin County Level 1 Snow Emergencies, but that is usually triggered after there is some accumulation on the ground. While EasyMile had completed testing in cold and snowy climates, it became clear that the new Gen3 EasyMile EZ10 vehicles were much more sensitive to weather than expected. Previous generations of the shuttles have received many software updates to address navigating during light snow and rain events because they have been operating for a greater time. The new shuttles, while safe to operate, contained a much more complex suite of sensors that also receives software improvements to enable operation in a broader set of weather conditions, but is still in development. In the interest of safety, EasyMile restricted the Operational Design Domain until navigational capabilities during weather events is improved.

May Mobility's vehicle had manual control capabilities that enabled the vehicle to operate at speeds up to 25 mph, whereas EasyMile's vehicle capped the manual operation intentionally at 4 mph due to the potential safety risk to a standing operator who is using both hands to manually control the vehicle, should the vehicle stop suddenly. Therefore, the Smart Circuit was able to operate, albeit manually, in more weather events than the Linden LEAP. Overall, the technology currently being deployed has some limitations during weather events that will need to be refined before the vehicles can be used in a permanent operation where the local climate could impact the automation.

Figure 13-6 summarizes the general timeframe for the project as it relates to CEAV's major activities.

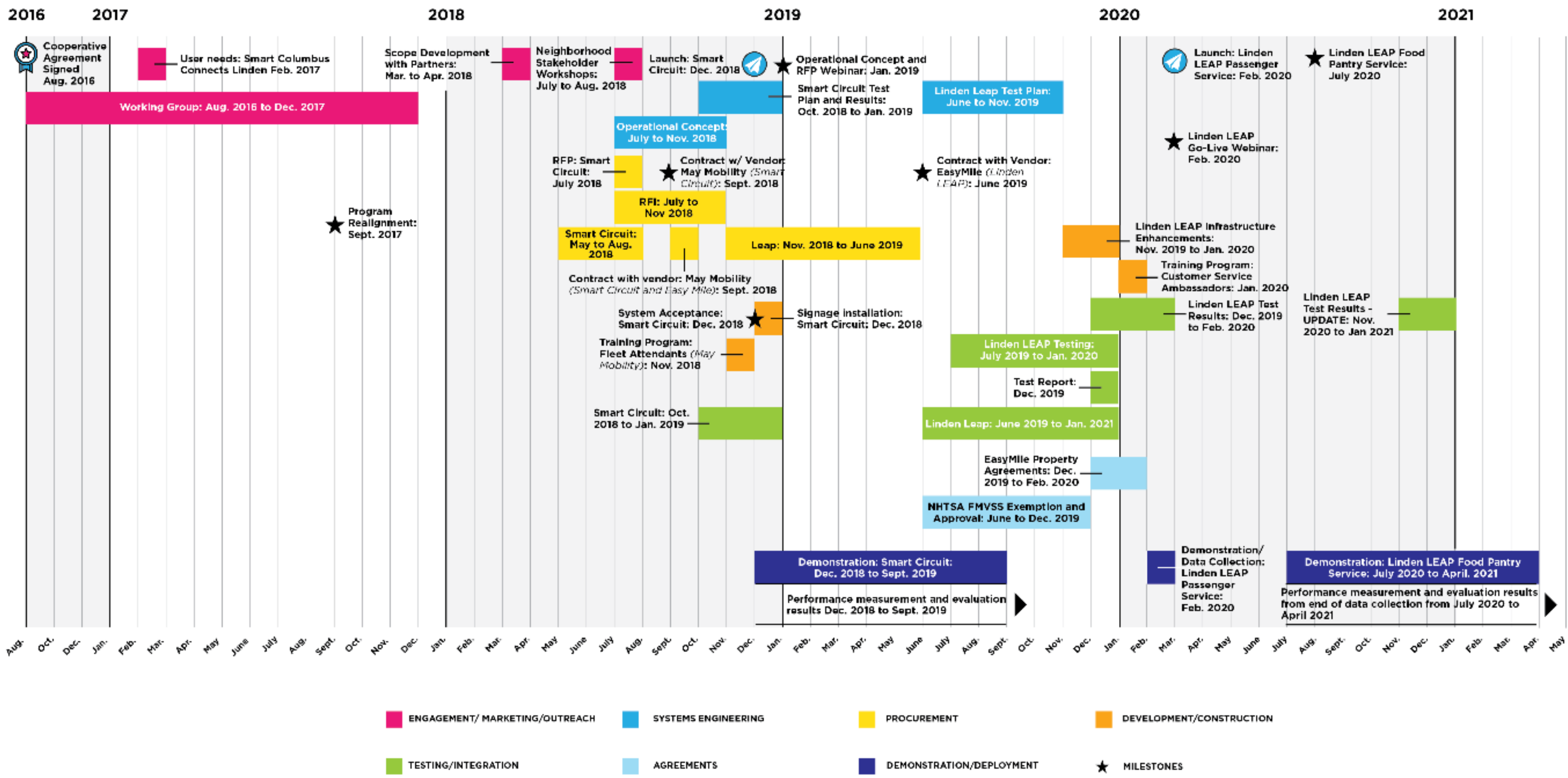


Figure 13-6: Connected, Electric, Autonomous Vehicles Project Timeline

Source: City of Columbus

13.2.6. Project Launch

13.2.6.1. SMART CIRCUIT

Leading up to the deployment, the project team engaged the many partners and stakeholders to preview the route and technology. Since this was a learning experience for the region, a goal was to build knowledge, awareness and competence among residents and community leaders, as well as the project team. As such, the media was also engaged to help create awareness for the deployment, generate ridership and educate the public on AV technology. When the RFP was published late spring 2018, the goal was to begin operations that year. Following procurement, route setup, and testing, the service launched on December 10, 2018.

Three approvals were needed for the vehicles before service could begin. Per Governor Kasich's Executive Order 18-04K, the vehicles needed to be licensed for operation through ODOT's DriveOhio group. The second approval was with the Public Utilities Commission of Ohio (PUCO), which needed to register the provider as a commercial transportation company. The third was with the Bureau of Motor Vehicles, which provided the license plates and registration for the vehicles.

No federal approvals were required for the first CEAV deployment, as the May Mobility vehicles were equipped with standard vehicle controls for an operator to use and drive the vehicle manually as a backup to the automated driving systems.

13.2.6.2. LINDEN LEAP

EasyMile was selected for the second deployment and provided its own vehicles for the service. These vehicles were different from the first deployment in that they were built from the ground up to be automated with no operator on board. The vehicles do not have standard controls like a steering wheel and pedals, and therefore needed to receive federal permission to operate before being imported from France.

The second deployment was initially planned to launch in November 2019; however, some delays were experienced in receiving approval of the route and operation of the vehicles from NHTSA. The importer – EasyMile – needed to submit the Vehicle Identification Numbers and the route to NHTSA for approval. This process gives NHTSA the opportunity to review the route and provide input.

Incorporating NHTSA's feedback on the route was an intensive process, but necessary to ensure safety. Two key pieces of feedback from NHTSA that resulted in route and service modifications were the proximity to elementary schools and daycares as well as the vehicle traveling down the center of the roadway on narrow streets with parked cars along both sides. Also, the City had to make a commitment to install signage along the route. There was a need to inform other drivers of the presence of an automated vehicle to increase awareness of the situation. It was an iterative process to address NHTSA's questions and concerns as they arose through a series of reviews and exchanges between EasyMile and NHTSA. With review and response time unpredictable, this time and effort was not something that had been fully budgeted for in the original project schedule.

At the state level, the DriveOhio and PUCO approval processes were very straightforward since the project team had gone through the process previously. However, approval by the Bureau of Motor Vehicles was not, since the vehicle type was not standard.

The vehicles were delivered on December 11, 2019, which enabled testing to begin, the vehicles to be wrapped with Smart Columbus and One Linden branding, and launch plans to be finalized. A launch date of February 4, 2020 was set, and several events were planned leading up to the start of operations. Partners involved in the first automated shuttle project in Columbus, as well as new partners to this project, were invited to early previews of the shuttle before it officially launched. The project team also coordinated with the Columbus Advisory Committee on Disability Issues to have its members experience the accommodations on the shuttle and provide feedback to both the City and EasyMile. These engagements provided an opportunity to educate on the service and share information that could be relayed to residents, and also allowed them the opportunity to ask questions.

The Linden LEAP launch was held at Douglas Community Recreation Center, the central stop on the route. The deployment was one of the most complex automated shuttle routes deployed in the U.S. at the time and became the first public, daily operating automated shuttle in a residential area in the nation. A press conference at launch was organized to help educate not only Linden residents but all Columbus residents about the new and exciting technology that would be traveling city streets. All local television outlets covered the announcement as well as local and national news outlets. Because the press conference was mainly geared toward educating the general public via media coverage, a parallel community-oriented launch was planned as well, where Linden residents were invited to test ride the shuttle, meet the vehicle operators, and engage in some tech-focused and AV-related activities. This event also showcased the local high school robotics team demonstrating its robots and The Ohio State University (OSU) displaying the shuttle simulation developed for this project to evaluate the shuttle's performance in a machine-in-the loop scenario before the vehicles began testing in the live environment. See **Figure 13-7** for a photo from the launch event.

Figure 13-7: Linden LEAP Launch

Source: City of Columbus

13.2.7. Demonstration

13.2.7.1. SMART CIRCUIT

Smart Circuit became not only the first AV deployment in Columbus, but also the first in Ohio when it launched for passenger service on December 10, 2018. During its ten-month operation, Smart Circuit carried 16,062 passengers, an average of 59 riders per day. Boardings at each stop are shown in **Figure 13-8**. The six shuttles drove 19,118 miles during the demonstration. Riders of the shuttles submitted 278 completed surveys to provide feedback on the experience and the technology.

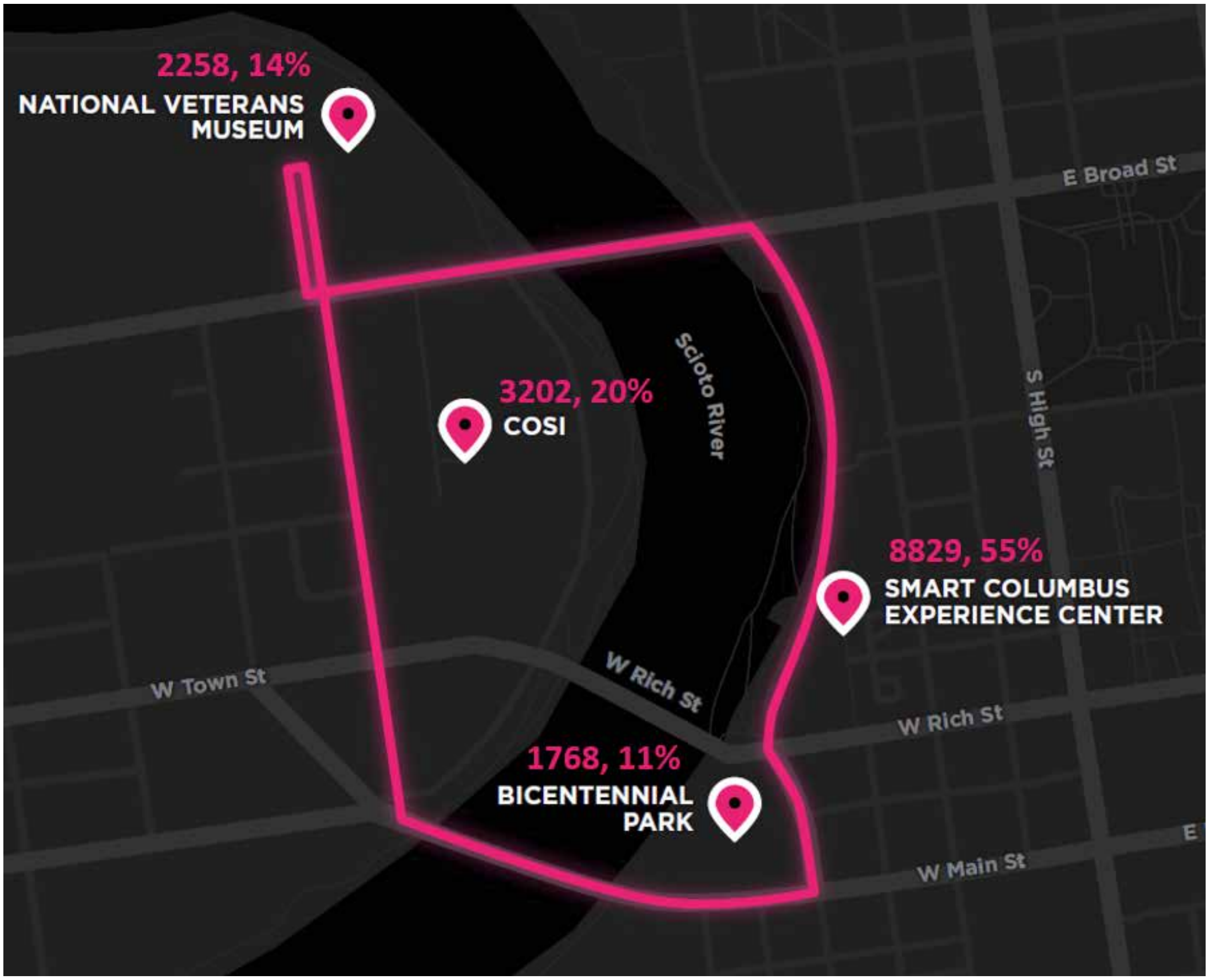


Figure 13-8: Smart Circuit Stations and Ridership

Source: City of Columbus

The Smart Columbus Experience Center stop was the most popular among Smart Circuit riders, with 55% of ridership using that stop. Visitors to the center were often informed about the shuttle service and chose to take a ride. An unexpected result of providing the service was that it was regularly used by some commuters who would park on the west side of the river where parking was cheaper and use the service to travel into downtown. These commuters typically would board the shuttle at the National Veterans Memorial and Museum in the morning and then they would board at the Smart Columbus Experience Center in the evening.

While the contract did not enable the project team to secure detailed autonomy data from the deployment, May Mobility did provide a heat map (see **Figure 13-9**), showing where the autonomy was higher and lower. Intersections, adjacent parked vehicles, and pedestrian crosswalks were the areas that had lower autonomy. The intersection of West Town Street and Belle Street at the southeast corner of COSI was unsignalized, so May Mobility required the manual operation of the shuttles to cross this two-way stop-controlled intersection because the vehicles could not do so autonomously at the time.

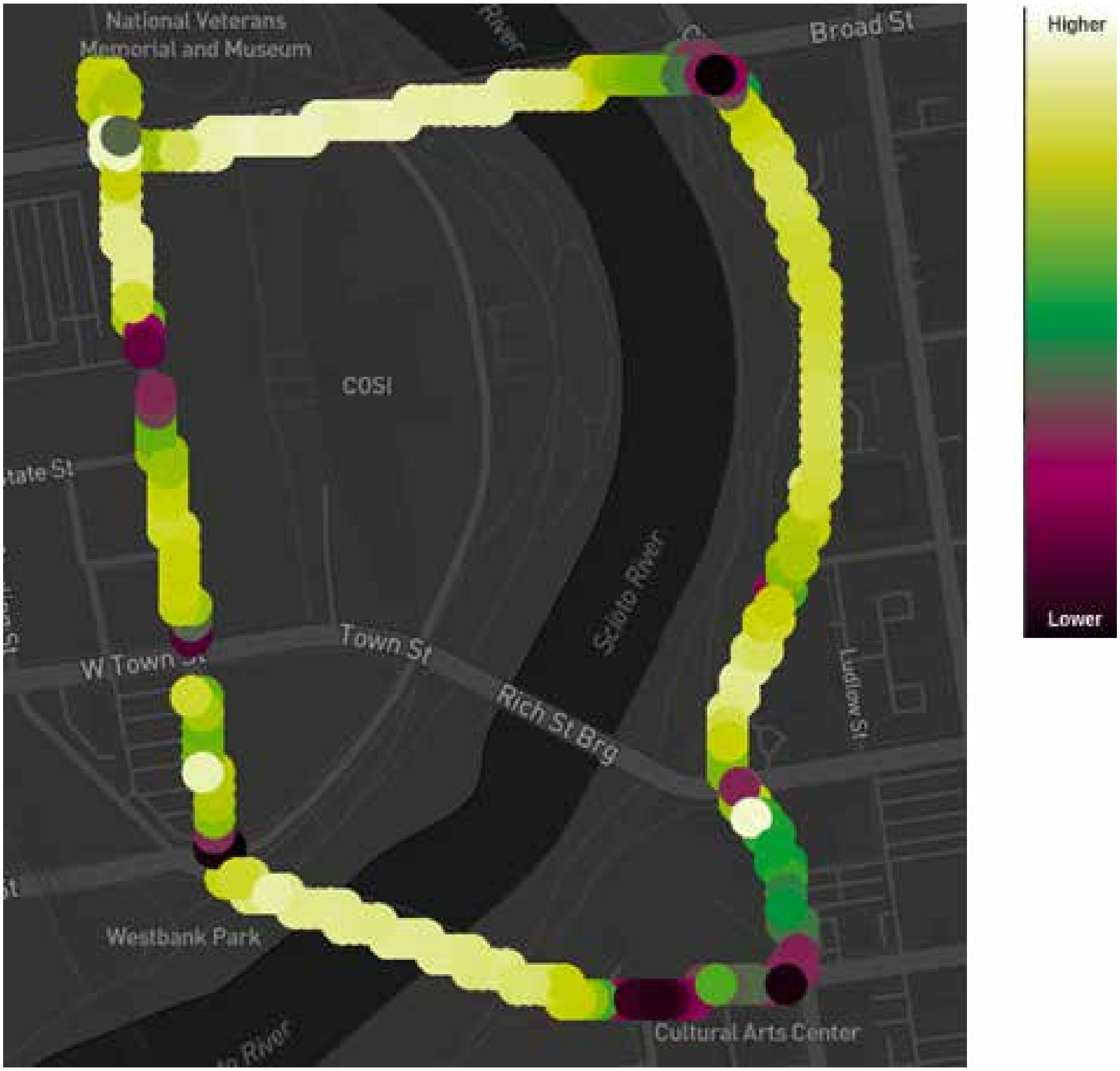


Figure 13-9: Smart Circuit Autonomy Insights

Source: May Mobility

The development of SOPs was viewed as a key document for the safe operation of a shuttle in the public space. This document outlined normal day-to-day operating scenarios as well as procedures to navigate to planned events, such as festivals and construction, and guide the team's response to unplanned events like weather and unruly passengers. Given the route's location, it was anticipated there would be frequent service interruptions due to the recurring festivals and races along the Scioto River. A planned events playbook supplemented the overall SOP document by identifying all the festivals and races and the planned alternate route to be used. It also developed a coordination process to prepare for and communicate upcoming events to riders.

13.2.7.2. LINDEN LEAP PASSENGER SERVICE

The Linden LEAP passenger service was in operation for about two weeks. On February 20, 2020, one of the Linden LEAP shuttles was traveling at 7.1 mph and came to a sudden stop. As a result, one of the two passengers onboard slipped from her seat to the floor and sought medical attention. The City promptly suspended operation of both Linden LEAP shuttles, pending a review from an Incident Review Panel.

On February 24, EasyMile arrived to initiate its review. The next day, NHTSA suspended all U.S.-based operations of EasyMile pending a safety evaluation. Upon review, EasyMile determined that a slight deviation in the steering of the shuttle, similar to the steering wheel slipping in a car, caused the sudden stop on February 20. This steering deviation did not align with the established safety chain rules within the vehicle, which is programmed to stop when it detects a discrepancy between the defined rules and current conditions. Factors including weight distribution and road conditions can also affect the vehicle’s ability to meet the safety chain requirements and, therefore initiate a stop of the vehicle.

EasyMile worked closely with NHTSA to complete the safety evaluation. With input from the City of Columbus, the Incident Review Panel, and the ten other U.S. stakeholders operating EasyMile shuttles, EasyMile developed a Passenger Safety Enhancement Plan. The plan details changes needed before all U.S. shuttles could return to passenger service. These changes included:

- Audio alert reminding passengers the vehicle can make sudden stops
- Additional signage
- Additional operator training on safety
- Alternative manual remote for the operator
- Operator performance measuring
- Seat belts installed on all vehicles

During its initial two weeks of operation, 50 passengers took rides on the Linden LEAP. **Figure 13-10** shows the autonomy percentage of the Linden LEAP passenger service, based on data from the EasyMile Application Programming Interface (API) that reports data on the status of the vehicle to the Smart Columbus Operating System (SCOS) every two seconds. The vehicles operated at greater than 70% automated mode on a challenging route due to vehicles parked adjacent to the route and the narrow width of some of the roadways.

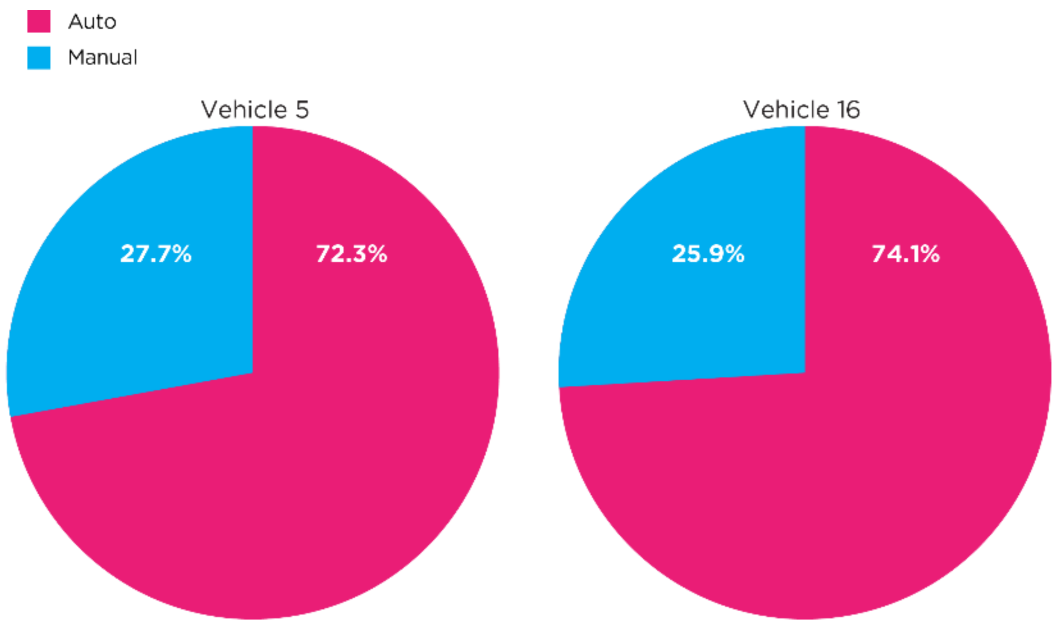


Figure 13-10: Mode Split for Linden LEAP Passenger Service Autonomy

Source: City of Columbus, https://discovery.smartcolumbusos.com/visualization/w7xtg5sc

13.2.7.3. LINDEN LEAP FOOD PANTRY SERVICE

As discussed above, the Linden LEAP food pantry service emerged as a result of several pandemic-related factors. First, state and local guidelines stressed the importance of “social distancing,” defined as maintaining six feet of separation from another person, and increasing the necessary sanitizing procedures, which greatly limited the ability of the EasyMile EZ10 shuttles to accommodate passengers. Second, as the City of Columbus consulted with its stakeholders to determine how the shuttles could otherwise be used to serve the immediate needs of the community, it was recognized that there was a localized and increasing need in the community to connect residents to food and support services.

When the pandemic-related directives went into effect, the on-site food pantry at St. Stephen’s Community House shifted from a choice food pantry, where patrons would choose food from shelves to take home, to a pre-packaged system. St. Stephen’s also saw a significant increase in demand during this time. Therefore, it was proposed that the Linden LEAP transform its mission to a food pantry box delivery service that picked up boxes from St. Stephen’s and traveled to Rosewind, the largest public housing development in the City of Columbus. By using the food pantry delivery service, the shuttles would be able to serve many households throughout the pandemic to help alleviate food insecurity.

The City of Columbus submitted Appendix A[120] of the OpCon to USDOT to request approval for the detailed alternate use case for the shuttles. Cooperative Agreement regulation 2 CFR §200.313(c)(2) allows the Federal Government to approve temporary use of grant equipment for non-federally funded programs or projects, provided that such use will not interfere with the work on the projects or program for which the grant equipment was originally acquired. Based on this statute, USDOT authorized the temporary non-program use because, due to the pandemic, the shuttles were not performing their originally approved

[120] *https://d2rfd3nxvhnf29.cloudfront.net/2020-08/SCC-B-CEAV-OpCon-APPENDIX_A-clean.pdf*

program use of carrying passengers. Without the impact of the pandemic, it is estimated that the vehicle mitigations would have been installed and the service re-launched in late May or early June 2020.

> ***"I believe it is a convenient service. I think that, ya know, especially for those who don't, aren't blessed enough to have a car and be able to drive there, they can walk straight from there to the neighborhood and get food for their family I think it's awesome."***
>
> *– Food pantry patron survey response*

The food pantry service ultimately launched on July 30, 2020, following coordination with stakeholders, implementing minor route modifications to reflect the shorter route, and hiring and training operators on the food pantry operations. The shuttle departed St. Stephen's and traveled to Rosewind, where operators distributed food pantry boxes from noon to 3pm, Monday through Friday.

As identified in **Table 13-1**, the service delivered 3,598 boxes and 1,526 masks into the community from July 30, 2020 through April 1, 2021.

Table 70: Total Boxes and Masks Distributed

Total EasyMile Boxes Distributed	Total Mask Packs Distributed	Walk Up Percentage
3,598	1,526	8.08%

Source: City of Columbus, https://discovery.smartcolumbusos.com/visualization/fk4uzefz

Weekly distribution numbers are shown in **Figure 13-11** to illustrate the number of boxes distributed at the St. Stephen's food pantry (blue) and the number of boxes distributed in Rosewind by the shuttle service (pink). The shuttle service averaged 100 boxes per week throughout the project and saw strong and steady distribution throughout the project. The pantry at St. Stephen's averaged 468 boxes per week, and had strong distribution through the end of 2020. In 2021, the numbers declined as unemployment benefits were implemented and the economy began to recover from the pandemic. Over 8% of the food pantry service patrons walked to the shuttle and did not drive, so bringing the food into the community eased the two-mile walk to and from the food pantry with a 30-40-pound box. With each box containing three meals per day for four people, and three days' worth of food, **the Linden LEAP pantry service distributed 129,528 meals into the community during its eight months of food delivery**.

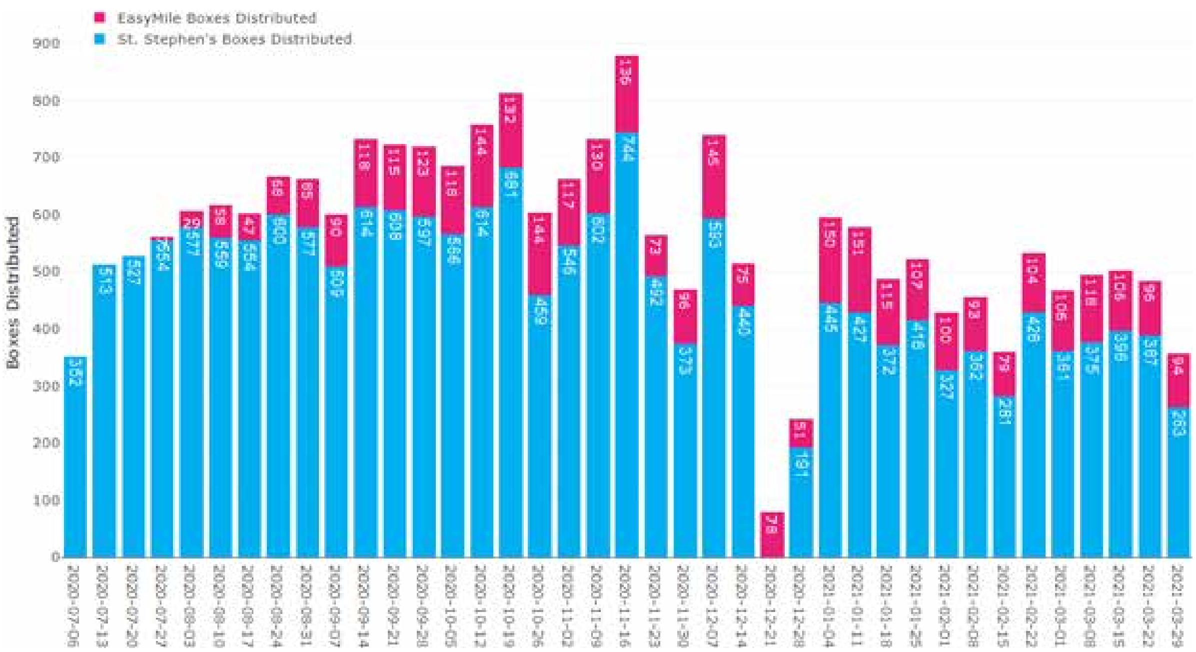


Figure 13-11: Weekly Food Pantry Boxes Delivered

Source: City of Columbus, https://discovery.smartcolumbusos.com/visualization/aeppl0zl

Figure 13-12 illustrates the daily average of boxes distributed by month at St. Stephen's (blue) and by EasyMile (pink).

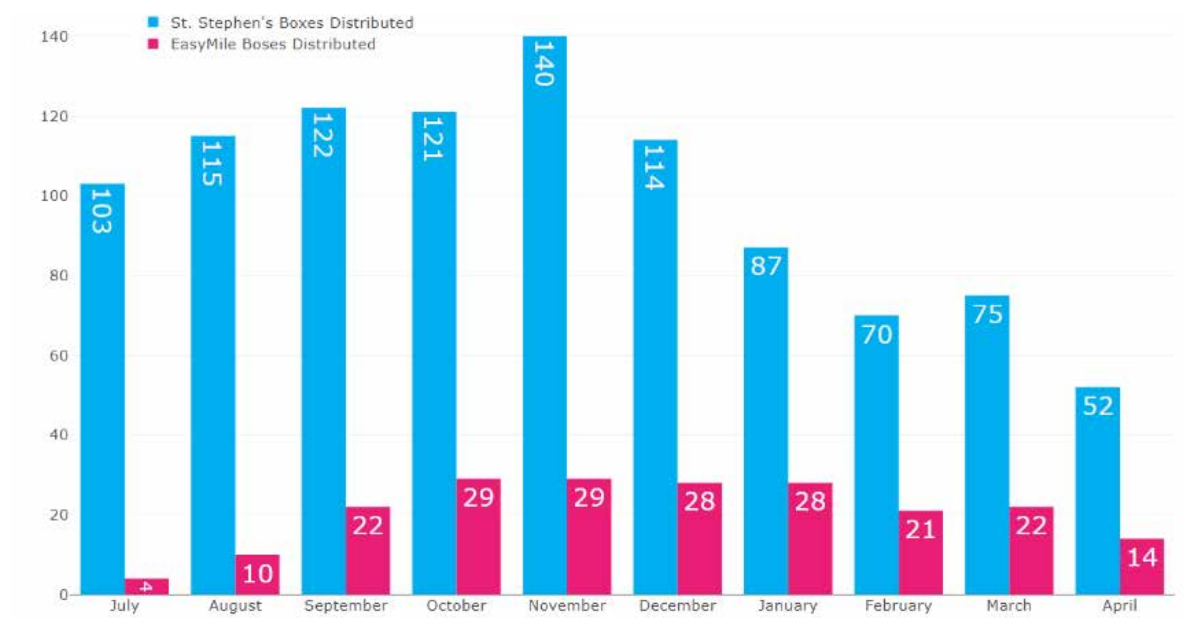


Figure 13-12: Average Daily Pantry Boxes Delivered

Source: City of Columbus, https://discovery.smartcolumbusos.com/visualization/k1yyjw2

Due to the high demand for food pantry boxes at the St. Stephen's Community House, boxes and bags to put the food in were in short supply. The City continued to engage with its partners to solicit bag donations to support the effort. Many entities were able to provide bags with corporate logos, typically from trade shows, to support the distribution of food. The Columbus Zoo provided paper bags which were doubled up to support the weight of the contents. Without this gracious support from partners, the distribution of food into the community would have been more challenging.

Table 13-2 shows the donations provided. It is important to note that depending on the food available and the size of the bags, more than one bag may have been necessary to accommodate the provisions so the bags donated do not correlate 1:1 with the numbers of "boxes" distributed.

Table 71: Bag Donations from Partners to Support the Food Distribution

Donor	Number of Bags Provided
CareSource	150
Ohio Health	150
Battelle	243
Columbia Gas	250
Smart Columbus	40
Mount Carmel	400
Columbus Zoo	8,000[121]
Columbus Airport	20
Total	9,253

Source: City of Columbus

Figure 13-13 displays the shuttle autonomy percentage during the food pantry service, which was around 50% for this phase of the demonstration. The reasons that the autonomy was lower for the food pantry service than the passenger service were primarily operators switching to manual to pull the vehicle over to distribute boxes to residents along the route, food pantry queuing in the St. Stephen's Community House parking lot, and navigating around parked cars that slowed the vehicles. The service's intent was to bring boxes to the Rosewind station, but some families met the shuttle along the route and were given pantry boxes. While close objects, like parked cars, can slow the shuttles, when passengers were on-board the operators remained in automated mode for the passenger experience. However, during the food pantry service, the operators switched to manual mode more frequently for time and travel speed purposes. In the St. Stephen's parking lot, with the switch to prepackaged boxes to reduce the spread of COVID-19, the food pantry line was organized based on vehicular flow to allow for on-site queuing rather than having vehicles backing up onto 17th Avenue. This meant that the operators were driving manually in the parking lot to navigate around queued cars and cones.

[121] *The paper bags were often double-bagged due to the weight of the goods.*

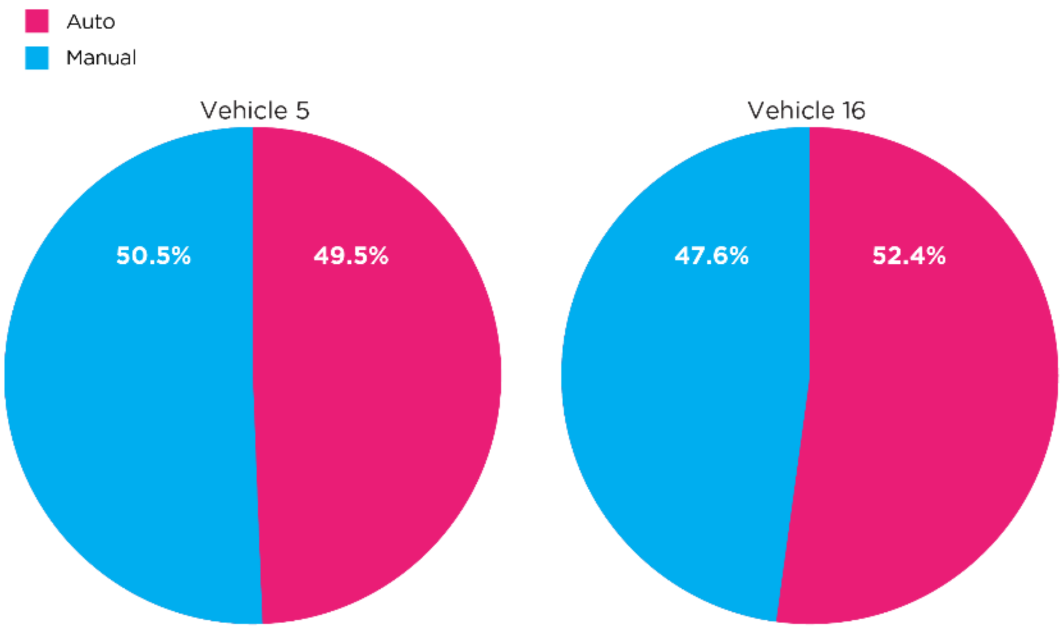


Figure 13-13: Mode Split for Linden LEAP Food Pantry Service Autonomy

Source: City of Columbus, https://discovery.smartcolumbusos.com/visualization/vmmu102a

The data collected in the SCOS also showed the operating speeds of the vehicles at all times along the route. Each of the route segments had its own characteristics that could impact the operating speeds or the autonomy.

Figure 13-14 shows the average operating speed by segment. The faster traveled road segments (magenta) were in Rosewind, where there were rarely parked cars interfering with operations and the roadway width was greater. The slower traveled road segments (light blue) were 15th Avenue and 18th Avenue, with parked cars on both sides of travel down the center of the lane, and the St. Stephen's Community House parking lot, where the on-site food pantry traffic frequently slowed the vehicle.

Figure 13-14: Linden LEAP Food Pantry Service Average Speed (mph) by Segment

Sources: City of Columbus (data), https://discovery.smartcolumbusos.com/visualization/cd12h84u and Kepler (visualization), https://kepler.gl/demo/map?mapUrl=https://dl.dropboxusercontent.com/s/gyxfd5308smkkyn/keplergl_oulyyon.json

Figure 13-15 shows the segments that have higher operating autonomy (magenta) compared with segments that have lower operating autonomy (green).

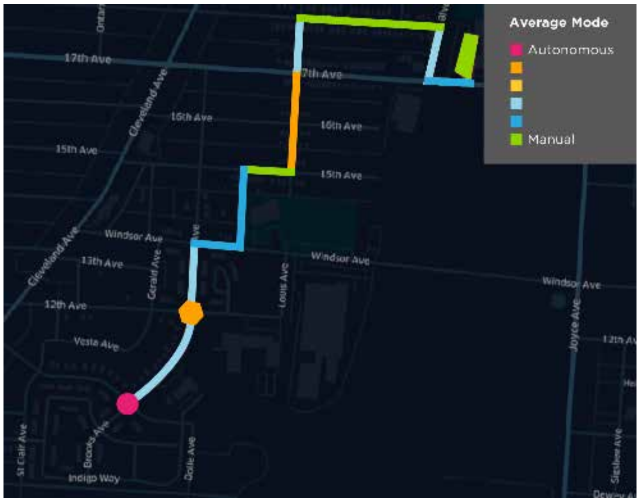


Figure 13-15: Linden LEAP Food Pantry Service Autonomy by Segment

Sources: City of Columbus (data), https://discovery.smartcolumbusos.com/visualization/snvituov and Kepler (visualization), https://kepler.gl/demo/map?mapUrl=https://dl.dropboxusercontent.com/s/gyxfd5308smkkyn/keplergl_oulyyon.json

"Man, it was wonderful. Give you a grade on it? Outstanding, A-plus. It was really unexpected. It was like right there. Then as I began to come like every week it just became a habit, I just got going every week."

– Food pantry patron survey response

Of the 80 survey respondents who used the CEAV Rosewind food pantry, 77 indicated their mode choice of travel. Eleven individuals reported that they walked to the site, 40 used their personal vehicle, 23 received a ride from friends and family, one used a bicycle, and two used bus transit. This represents an increase from 4% (1 out of 24) walking to the St. Stephen's food pantry site to 14% (11 out of 77) walking to the Rosewind food pantry site. As shown in **Table 13-3**, more than 80% of patrons were satisfied with the convenience of the service.

Table 72: Post-Deployment Findings from Online Survey

Outcome	Post-Deployment	Data Source
Walk-up usage of AV Rosewind food pantry	14% of the food pantry patrons walked to Rosewind	Online survey
Walking distance to AV Rosewind food pantry	Ÿ 8 walked <0.5 miles Ÿ 2 walked 1-2 miles	Online survey
Perceived convenience of AV Rosewind food pantry	Ÿ 64% waited <5 minutes Ÿ 80-90% extremely satisfied	Online survey
Perceived reliability of AV Rosewind food pantry	Ÿ 27 repeat patrons (2-5 times) Ÿ 8 repeat patrons (6-9 times) Ÿ 10 repeat patrons (10+ times)	Online survey
Perceived accessibility of food pantry service	Ÿ 44% do not rely on a personal vehicle Ÿ 25% obtained most of their food from food pantries Ÿ 55% made weekly or monthly trips to the food pantry	Online survey

Source: Online Survey Responses

13.2.8. Communications

With automated driving systems being considered emerging technology, it was important to engage the community early to understand the potential barriers to adoption. The audiences for the two deployments were different. The Smart Circuit route was in the downtown area. Adjacent to the route were parkland and government buildings, with few private residential or commercial buildings. Communications and outreach involved the cultural institutions on the route (COSI museum and the Veteran’s Memorial), City of Columbus Recreation and Parks staff, and community partners and business organizations, including The Columbus Partnership. Potential riders were therefore likely visitors to the downtown or people who worked nearby. The Linden LEAP route, in contrast, ran through a residential area, adjacent to dozens of homes and apartments, as well as numerous churches, schools and other organizations. The Linden LEAP deployment therefore necessitated a wider reach to build awareness of the project, solicit input, and develop community support.

13.2.8.1. KEY AUDIENCES AND OBJECTIVES

The Smart Circuit deployment was intended to create knowledge among both the project team and the public in Columbus, the State of Ohio and beyond. The communications objectives and audiences for the deployment funded by The Columbus Partnership and DriveOhio were to:

- Create educational experiences before, during and after residents engage with the shuttle to influence understanding and acceptance of the technology
- Foster “ground-up” community enthusiasm and pride for Columbus’ technology leadership
- Engage, align and mobilize community leaders and influencers to educate the community on the shuttle, the technology and its benefits
- Facilitate knowledge transfer with project teams, partners and peers nationwide, on the capabilities of AV shuttle technology
- Demonstrate Columbus and Ohio’s leadership, capabilities and assets in the testing and deployment of automated vehicle technology nationally

The priority for the Linden LEAP deployment was to educate residents and organizations who lived or operated near the route about the shuttles, and to invite residents to use them to access community services and mobility options. The communications team sought to ensure safe on-street interactions with the vehicles. Finally, the communications team sought to create pride in the pioneering deployment among the greater Linden community, and the greater Central Ohio region.

13.2.8.2. KEY MESSAGES

A working group of the City of Columbus, The Columbus Partnership, DriveOhio and May Mobility was convened to develop and implement a communications plan and assemble an advisory committee of 15 local stakeholders to advise and support the communications planning. For the Smart Circuit deployment, the project team sought to create a messaging platform that would help generate local excitement and pride for the deployment of the shuttles, but also would not over-promise on what the new technology could deliver. The messaging platform “Be a Part of the Start” was created. The messaging helped to convey that taking a ride was a chance to contribute to the community’s foundational understanding of automated driving systems and welcome a new, future-forward industry to the region.

Key messages for Smart Circuit included:

- The future of transportation starts in Columbus.
  - Smart Circuit is Ohio’s first automated shuttle.
  - Smart Circuit offers residents and visitors a hands-on educational experience with automated technology.
  - Engineers, researchers, and policymakers from the City of Columbus, The Columbus Partnership, DriveOhio, and OSU will use the demonstration to inform future deployments of automated driving systems.
- Automated vehicles can strengthen the economy and the neighborhoods.
  - Smart Circuit brings the City one step closer to ensuring equitable mobility for all Columbus residents, and to safer, less congested streets.
  - The Columbus region is already a pioneer in automated driving systems research and development – the technology has been researched at OSU and tested in a safe closed environment at Transportation Research Center. Smart Circuit takes that work one step further by demonstrating the technology in a real-world environment.
- Inviting riders to experience the technology themselves.
  - Smart Circuit offers Columbus residents and visitors firsthand experience with the technology, many for the first time.
  - By taking a ride on Smart Circuit, everyone in the community has the chance to be “part of the start” of a new era of mobility innovation in the region.
  - Riders were invited to experience the technology, ask questions of the vehicle operator, and share the feedback via social media or the post-ride survey.

When selecting the route and developing the Linden LEAP messaging, the City of Columbus contracted with the Community of Caring Development Foundation, which is affiliated with New Salem Church, a large Baptist church in the Linden area, to advise the team. This third-party input and validation from a trusted community organization helped strengthen and localize the messaging, and also lent the project credibility with community members.

The Linden LEAP messaging emphasized the benefit to the community, tapped into community pride, reinforced safety, and noted the demonstration was a temporary pilot. The communications team was sensitive to historical distrust of government testing new things in communities of color. Therefore, consideration was given to the language used; for example: pilot versus test or experiment, emphasizing that while automated driving systems are new, they have been researched for decades and implemented in many areas. The project team also tapped into the pride of the community and positioned this as an opportunity for Linden to be a pioneer in this space and shape how the technology is deployed in other neighborhoods that look like Linden. It was emphasized that automated driving systems in the U.S. have federal oversight through the NHTSA.

The key messages included:

- The Linden LEAP – Linden Empowers All People – was created to pilot automated driving systems technology in a neighborhood, and to fill gaps in transportation so that residents can more easily connect with community resources.
- The Smart Columbus Program leverages technology to help reduce barriers to jobs, education, health and wellness, recreation and other resources.
- Linden is at the forefront of helping to shape the future as it relates to smart transportation options.
- Years of research demonstrate that the automated shuttles are safe, efficient and innovative.

13.2.8.3. KEY STRATEGIES AND TACTICS

The Smart Circuit team prioritized communications methods that enabled information and messages to be shared through trusted community partners and leaders, as well as through the local and national media. Before the route opened to the public, more than 100 partners and community leaders were hosted in a series of Partner Preview events. Partners were briefed on the educational objectives of the shuttle deployment and on May Mobility's technology. Most important, partners had the opportunity to take the first rides aboard Smart Circuit so they could personally endorse the service.

Three media moments were leveraged to drive local, national, and trade coverage of the deployment. In September 2018, it was announced that May Mobility had been selected to provide and operate the vehicles. A stationary May Mobility vehicle and key spokespeople were made available to members of the media before vehicle mapping and testing began to let the public know that the vehicles would soon be operating on public streets. In December 2018, during the days before the route opened to the public, another media event was held and offered reporters inaugural rides inside the vehicles, where they were welcome to shoot photos and video, and conduct interviews with spokespeople.

To achieve the Linden LEAP's communications objectives, a key strategy was to identify ways to co-create with the community. A few examples of this include getting community input in naming the shuttle, working with a local shuttle operator, EmpowerBus, to hold hiring events for the operator positions in the community, and working with the local high school to highlight achievements of its robotics team in the shuttle's launch activities. EasyMile contracted with EmpowerBus to staff and operate the shuttles for the passenger service. Through the local hiring events, EmpowerBus received 40 applications, 19 of which interviewed on the spot. Seven out of nine operators for the shuttle service hired by EmpowerBus came from the Linden community. A workgroup was formed that consisted of community members and communication professionals, who met to inform messaging and strategy, so the communication activities were vetted and right-fitted for the community. These opportunities helped foster community buy-in to the project.

Figure 13-16: EmpowerBus Operator Hiring Event at St. Stephen's Community House

Source: City of Columbus

Figure 13-17: Greater Linden Business Network Takes a Ride on Smart Circuit

Source: City of Columbus

Another key strategy was early exposure of key community members to the shuttle. The City of Columbus identified key community stakeholders and created ways for them to experience the shuttle prior to launch. The communications team worked with the Greater Linden Business Network to host its monthly meeting at the Smart Columbus Experience Center, where a presentation on the shuttle project was given, and rides on the Smart Circuit were offered. For all of them, this was their first experience with automated technology, and they reported favorable opinions of the technology after their ride. Then as the launch of the Linden LEAP approached, partner previews were offered where there was a short presentation on the shuttle and a test ride on the closed course test route was offered.

> In a community where a lot of information is shared via word-of-mouth, it was important to **equip leaders with information,** so they would be prepared to easily correct misinformation circulating in the community.

Information was shared with people who would be directly affected by the shuttle, including Rosewind residents, community members who use services at St. Stephen's, Douglas Recreation Center or the Linden Transit Center, and businesses, churches and schools along or near the route, as well as people in the community at large through churches, community organizations, business associations, and the local high school.

Two ambassador trainings were held to provide residents with information in advance of the shuttle launch. The training included the CEAV project manager, a speaker from DriveOhio to talk about the impact of this pilot on statewide automated technology pilots, a shuttle operator, and a representative from the Community of Caring Development Foundation. This encouraged community members to ask questions and get those questions answered in a low-risk environment. It also helped build trust in the community and create support. In a community where a lot of information is shared via word-of-mouth, it was important to equip leaders with information, so they would be prepared to easily correct misinformation circulating in the community.

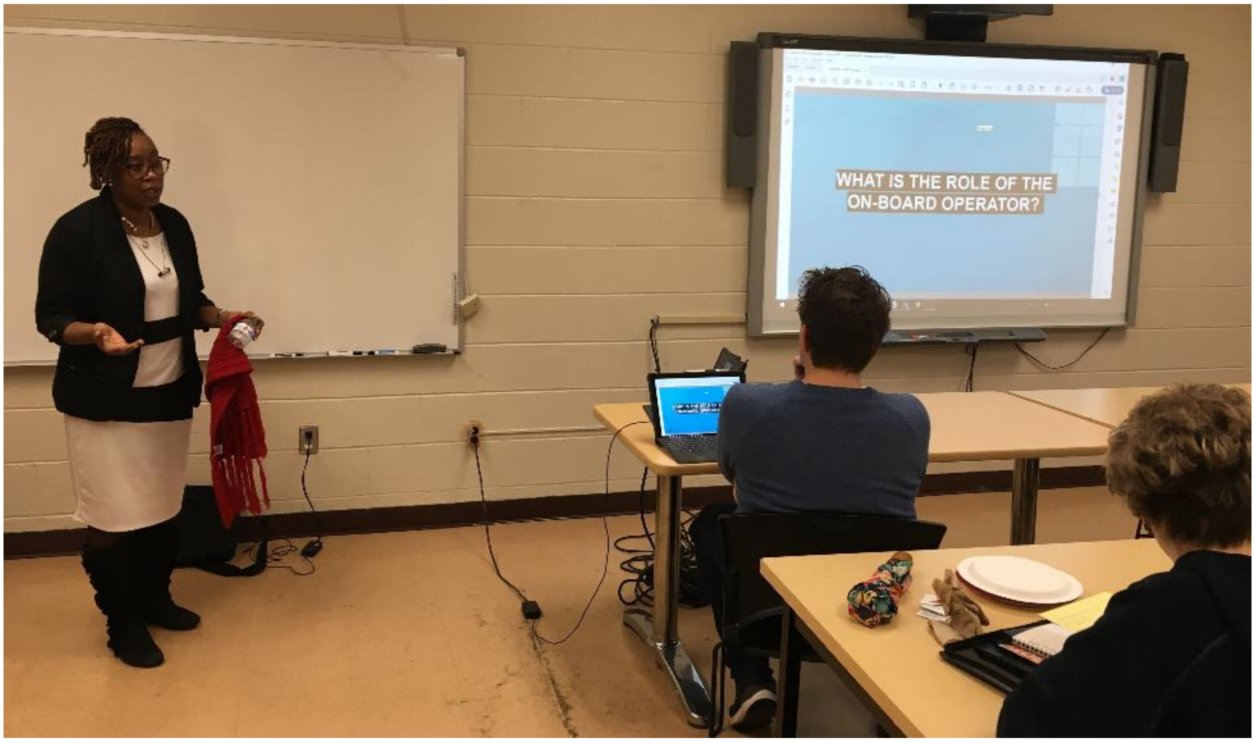


Figure 13-18: EmpowerBus Operator Conducting Linden LEAP Ambassador Training

Source: City of Columbus

Another key strategy was to ensure that the details about the shuttle and launch of the project were shared early. The earliest communications shared the goals of the project; as more details were solidified, such as the route and the vendor, this information was also shared. This incremental approach helped the community to feel brought along in the process before launch. The community partners shared this information on social media, in newsletters and in meetings.

When testing began, the communications kicked into high gear. The prelaunch campaign included messaging that the Linden LEAP was “coming soon” and shared details about what residents could expect in the testing phase, including: where it would be, what times it would be active, and how vehicles and pedestrians should interact with it. A targeted mailer was distributed to 3,681 residents announcing the shuttle was coming soon and inviting them to the community launch event.

The mailer was reinforced by organizing a door-to-door outreach event where the team walked along the route and spoke with residents about the shuttle. Most residents indicated they had heard about the shuttle either through the mailer or from a neighbor and were either open to it or had a favorable opinion of it. Door hangers were left for residents who did not open their doors. The team also worked closely with the Columbus Metropolitan Housing Authority (CMHA) and attended its monthly resident council meetings in the months leading up to the launch. CMHA also agreed to print and distribute the project flyers to all its residents.

Figure 13-19: Canvassing South Linden with New Salem Community of Caring Development Foundation

Source: City of Columbus

Two events were organized for the launch of the shuttle: a press conference and a community launch. The press conference was geared toward technical project stakeholders and the media. The aim of the press conference was to showcase the project and exhibit the broad community support for the project.

The launch was used to draw ties to successes in technology by highlighting the recent win of the Linden McKinley STEM Academy's robotics team at a regional competition. They were congratulated on their success by the Mayor and joined him as the first official passengers on the shuttle, including being part of the ribbon cutting ceremony.

Figure 13-20: South Linden Area Commission Chair Lawrence Calloway, Jr., Speaks at Linden LEAP Launch Press Conference

Source: City of Columbus

Table 73: Participants in the Linden LEAP Media Event

Included Speakers	Honored Guests (Showed Support by Standing Behind the Speakers)
• CEO of St. Stephen's Community House • Chair of the South Linden Area Commission • City Councilmember • Mayor of Columbus	• Representatives from Linden McKinley STEM Academy • Pyramid Community Development Corporation • South Linden Area Commissioners • Greater Linden Business Network members • Rosewind Resident Council members • Community of Caring Development Foundation representatives • OSU staff • DriveOhio leadership • The ODOT Director • EmpowerBus leadership • EasyMile representatives • The Columbus Partnership staff • Smart Columbus PMO • Representatives from City Departments of Neighborhoods and Recreation and Parks • The Linden Liaisons

Source: City of Columbus

THE CITY OF COLUMBUS
ANDREW J. GINTHER, MAYOR

Figure 13-21: Linden LEAP Community Launch Event

Source: City of Columbus

The community launch event was geared toward community residents. Six stations held demonstrations of the automated shuttle modeling from OSU; test rides on the shuttle; question-and-answer session with an operator; demonstrations of the robots built by the Linden McKinley STEM Academy robotics team; and demonstrations with Ozobots (small robots) that were programmed to travel a map of the shuttle route. After participating in activities at each station, participants got their “passport” marked, and if they completed all the stations, they were entered to win one of several donated prizes.

After the launch, the overall communications shifted to education about how to interact with the shuttle as a passenger or driver. Posters were hung at each of the stop locations, providing details like hours of operation and encouraging feedback.

When the sudden stop incident took place on February 20, 2020, communications activities quickly pivoted to addressing the matter. The communications team managed media inquiries, developed statements, and served as spokespersons to share the most current information on the event and the status of the investigation. The workgroup was reconvened to better understand the community's response to the incident. Messages were developed with the workgroup that were shared through partner communication channels as more information became available. The goal was to be as transparent as possible throughout the process. The community appreciated the transparency and saw this as a learning opportunity.

Figure 13-22: Linden LEAP Food Pantry Flyer

Source: City of Columbus

After determining that the shuttle would be repurposed to address growing food insecurity due to COVID-19, the communications team regrouped and updated messaging, including developing a flyer and updating the website. The flyer was distributed at St. Stephen's, and Columbus Metropolitan Housing Authority agreed to print and distribute to its residents at Rosewind. The community partners distributed information through their communication channels including social media, newsletters, and in meetings. The shuttle re-launched in July 2020 through a virtual press conference and press release that also highlighted the launch of recruitment for the Connected Vehicle Environment (CVE) and the launch of the Smart Mobility Hubs (SMH) project. Because all three projects had a large footprint in the Linden community, it made sense to combine the announcements.

After the re-launch, community stakeholders were continuously updated about the progress of the shuttle; for example, expanding the capacity of distribution from 20 boxes to 40 boxes a day by deploying both shuttles to serve the purpose. The communications team also encouraged feedback about the shuttle by developing a survey card promoting the survey, as well as signage that was positioned at the shuttle during distribution.

13.2.9. Project Costs

The following charts and **Table 13-5** show the cost of deploying and operating the CEAV project and the specific vendors. Deployment covers the project beginning until the launch of the Smart Circuit on December 10, 2018, and Linden LEAP on February 4, 2020, respectively. Operations covers the launches until the end of the demonstration.

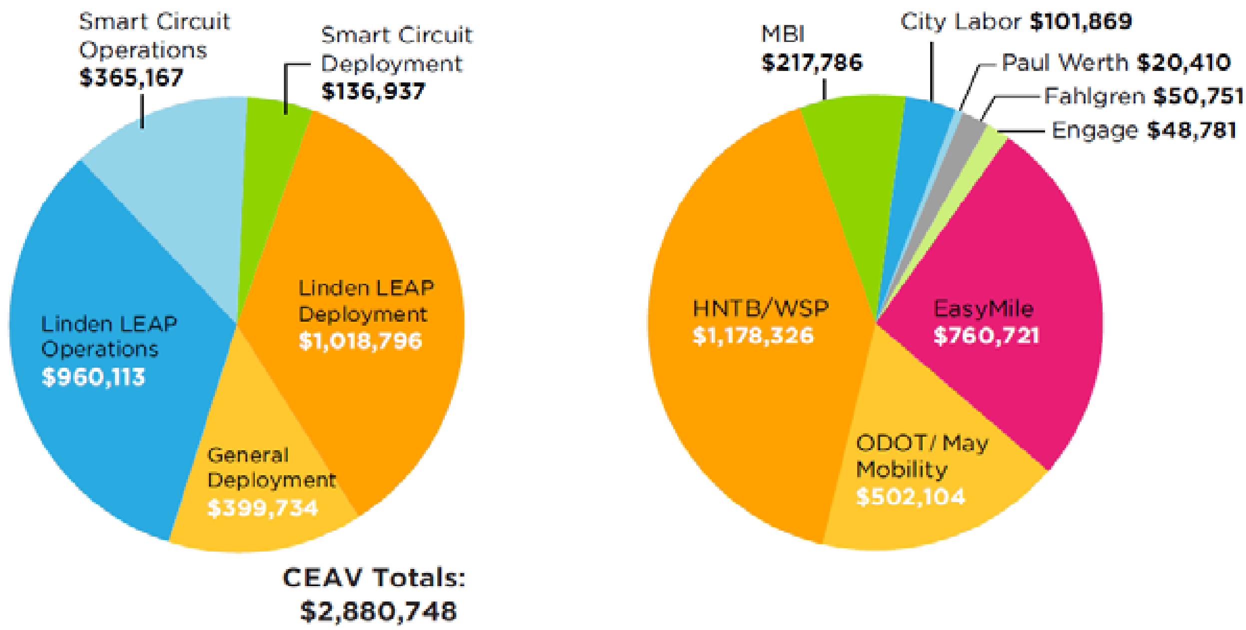


Table 74: Deployment and Operations Costs for the Connected, Electric, Autonomous Vehicles Project

CEAV Vendor	Deployment	Operations	Total
General Deployment Planning			
HNTB (WSP)	$360,068	N/A	$360,068
City Labor	$39,666	N/A	$39,666
Smart Circuit			
ODOT/May Mobility	$136,937	$365,167	$502,104
Linden LEAP			
EasyMile	$269,118	$491,603	$760,721
HNTB (WSP)	$472,488	$345,770	$818,258
MBI	$180,671	$37,115	$217,786
City Labor	$46,468	15,735	$62,203
Paul Werth	$15,129	$5,280	$20,410
Fahlgren	$6,782	$43,969	$50,751
Engage (MurphyEpson)	$28,141	$20,641	$48,781
Total	**$1,555,467**	**$1,325,280**	**$2,880,748**

Source: City of Columbus

13.2.9.1. KEY LEVERAGED PARTNERS

The Smart Circuit was deployed in conjunction with the key leveraged partners of DriveOhio (ODOT) and The Columbus Partnership. DriveOhio provided the contracting mechanism for the competitive bids, staff services, and provided some of the funding for the deployment. The Columbus Partnership provided funding and staff services for the deployment.

13.2.10. Project Team

Each project was led by the City, with vendor support playing a critical role in implementation. For the two CEAV project demonstrations, the vehicle vendors were responsible for delivering a turn-key solution including the vehicles and route set-up. Additional vendors supported the planning, documentation, testing and integration of system functionality. For CEAV, these vendors and their roles are summarized in **Table 13-6.**

Table 75: Connected, Electric, Autonomous Vehicles Project Vendors

CEAV Vendors	Responsibilities
EasyMile (EmpowerBus)	Ÿ Linden deployment vehicle vendor Ÿ NHTSA exemption Ÿ Operator training
May Mobility	Ÿ Scioto Mile deployment vehicle vendor
Michael Baker International	Ÿ Project manager and testing lead
HNTB (WSP)	Ÿ Systems engineering Route development Operational concept Ÿ Testing and documentation
Engage (Community of Caring Development Foundation, Linden Liaisons)	Ÿ Outreach and engagement
Paul Werth	Ÿ Recruitment and adoption
Fahlgren	Ÿ Recruitment and adoption

Source: City of Columbus

With each deployment, a coalition of stakeholders was assembled to assist in creating a community fashioned and successful project. While some stakeholders were involved in multiple facets of the project, each stakeholder is identified in **Table 13-7**, along with information on which phase or phases of the project they were involved in.

Table 76: Connected, Electric, Autonomous Vehicles Stakeholders

	Easton			Smart Circuit			Linden LEAP (Passenger)			Linden LEAP (Pantry)		
Stakeholder	Systems Engineering	Development	Demonstration	Systems Engineering	Development	Demonstration	Systems Engineering	Development	Demonstration	Systems Engineering	Development	Demonstration
Government												
ODOT/DriveOhio	X			X	X	X		X				
City of Columbus Department of Public Service		X			X	X	X	X	X	X	X	X
City of Columbus Department of Public Safety		X					X			X		X
City of Columbus Department of Recreation and Parks						X			X			X
South Linden Area Commission										X		X
Franklin County Engineer's Office		X										
Community-Based Organizations												
Columbus Downtown Development Corporation						X						
Celebrate One								X				
Columbus Metropolitan Housing Authority									X		X	
St. Stephen's Community House							X		X	X	X	X
Columbus Advisory Committee on Disability Issues							X			X		
Mobility Provider												
Central Ohio Transit Agency	X	X			X		X	X				

	Easton			Smart Circuit			Linden LEAP (Passenger)			Linden LEAP (Pantry)		
Private Entities												
Columbus Partnership	X			X	X	X	X					
Steiner & Associates		X										
Educational												
OSU	X				X			X			X	
COSI						X						
Tourism												
National Veterans Memorial and Museum				X								

Source: City of Columbus

13.3. PROJECT EVOLUTION

This section details how the CEAV project evolved from its conception during the development phase through the systems engineering process and ultimately to deployment.

13.3.1. Scope – The Proposal

The approved Volume 1 Technical Application for the USDOT SCC outlined a deployment for CEAVs in a live, mixed-use traffic environment, interacting with other vehicles, bicyclists, pedestrians, and other forms of transportation, and operating in an environment that included both signalized and non-signalized intersections. The deployment intended to bring a safe, efficient, accessible, environmentally friendly and easily expandable FMLM transportation solution to the program.

Three potential routes were planned to serve the retail, commercial, and warehouse centers in the Easton area, and create a connection to the recently opened, high-volume transit center located in Easton, as well as to the numerous parking areas within and surrounding this development (see **Figure 13-23**). The shuttle fleet was planned to use existing public roadways and use inductive charging stations to allow for fully automated operations, only requiring human interaction for regular safety and maintenance inspections.

Figure 13-23: Smart City Challenge Grant Proposal Easton Routes

Source: City of Columbus

The planned deployment was to incorporate six 12-passenger vehicles – two on each route – that are wheelchair-accessible, fully automated, electric and capable of speeds of up to 25 mph. Two proposed work center shuttle routes were to be synchronized with the schedules of the local employers and the COTA fleet, and would start and end at the COTA Transit Center. The retail shuttle would operate within the confines of the retail area, serving the largest parking facilities and retail amenities.

13.3.2. System Delivered

When it was determined that the routes proposed in the SCC application were too challenging given the current technology capabilities, the City of Columbus went back to the drawing board to identify how it could feasibly deliver the project. The result was the two deployments that served different purposes for the CEAV project. The Smart Circuit linked downtown visitors with cultural attractions and learning experiences, educating riders on the potential of automated vehicle technology. The project also served to educate the project team and partners on the capabilities of the technology and how to procure the services. The goal of the Linden LEAP was to provide a FMLM transit connection, until passenger service was permanently suspended due to the pandemic, transforming its mission from moving people to goods, to one moving goods to people.

The deployments did align with the original vision of automated and electric vehicles operating in a mixed-traffic setting. The Smart Circuit deployment did not have an accessible automated vehicle, though accessible accommodations were available if needed through a provided ride-hailing service. The project team saw a wheelchair accessible prototype vehicle introduced into the May Mobility fleet during the final month of operation, but it was not equipped with an automated driving system. The Linden LEAP vehicles were accessible vehicles.

13.3.3. Route Development

The Smart Circuit demonstration, funded and led by DriveOhio and The Columbus Partnership with the City supporting the effort, was completed rapidly, requiring many people to be involved in the process. A working group structure was established to keep partners apprised of project developments and to discuss critical decisions. This model served well through the deployment, so it was replicated as the City of Columbus transitioned into the second deployment.

To deliver the FMLM service in Linden, the City of Columbus convened a stakeholder group to provide input on potential routes and neighborhoods for deployment. Overall, the stakeholder group investigated 14 potential routes and how those routes could serve the community.

Route criteria helped guide the stakeholder group in selecting the route that would be the best fit for the demonstration. **Table 13-8** outlines each of the criteria and how improving connections with the CEAV could improve quality of life in the community.

Each proposed route was assessed against these criteria and how it could make a positive impact on the community. Part of the evaluation also included engineering and design factors, such as the road types and operating conditions along the route alignment. Driving the routes with an automated shuttle in mind helped narrow down some of the potential routes. As an example, a route that was to connect to a Kroger supermarket on High Street in Columbus was evaluated, but it involved traversing a very busy parking lot with frequent interactions with cars, pedestrians, and shopping carts, and did not appear ideal for automated vehicle operations based on system capabilities at the time. The 14 routes were narrowed down to four, at which point the project team solicited vendor input through a Request for Information (RFI) before selecting the final route that was deployed.

Table 77: Connected, Electric, Autonomous Vehicles Project Route Selection Criteria

Criterion	Description
Smart Mobility Hub	The route provides a connection to a proposed Smart Mobility Hub as part of the Smart Columbus initiative
Food and Service Access	The route connects to food and services needed within a community. The list includes grocery store, bank, pharmacy, and food bank/pantry
Ladders of Opportunity	The route connects residents with job or opportunity centers for enhanced placement access. The list includes an Opportunity Center and Ohio Means Jobs
COTA	The route connects to a COTA stop and acts as a FMLM connection to expand the reach of a traveler
Alignment Considerations	The route serves more as a missing link than a duplicate of an existing COTA route
Safety and Accessibility	The route has lighting and sidewalks in the vicinity of anticipated stops
Prenatal Support	The route connects pregnant individual with services that can aid in a healthy pregnancy
Neighborhood	The route connects to an opportunity neighborhood for increased mobility
Storage	The route provides a nearby facility for storage and charging of vehicles
Route Navigation	The technology at the time of deployment will allow the route to be traveled

Source: City of Columbus

13.3.4. Challenges

Challenges are to be expected with any project, but this is especially the case with emerging technology projects such as CEAV, where the technology is rapidly evolving, with multiple potential use cases to evaluate. Specific challenges in the delivery of this project included:

- **The sensitivity of the technology can cause the vehicle to react suddenly.** The on-board incident where a woman slipped from her seat during a sudden stop brought passenger operations to a halt immediately for an investigation. While the project team could still conduct test runs on the route, it was not able to carry passengers during the investigation. The City of Columbus convened an Incident Review Panel of independent experts to review information and recommend mitigations and cooperated with NHTSA's review of the incident. Upon review, EasyMile determined that a slight deviation in the steering of the shuttle, similar to the steering wheel slipping in a car, caused the sudden stop.
- **Even the best planning cannot accommodate unprecedented events.** The COVID-19 pandemic was an unanticipated challenge globally. Residents of Columbus and the state of Ohio at large were instructed to remain at home, only making necessary trips, such as for purchasing food. COTA requested that all trips on its buses be limited to essential travel and reduced routes, frequencies, and operating hours. Therefore, travel in the Central Ohio region sharply and immediately declined, a decline that was sustained through the remainder of 2020. Social distancing was required for all public transportation and was a difficult mitigation to implement in the small shuttles. Even as businesses began to open and the travel restrictions eased, most travel in the region did not recover to pre-pandemic levels during the project period. The full extent to which the project could have helped the community and showcased a true FMLM transit option was not able to be demonstrated.

The transition to a food pantry service did, however, provide a valuable service to the community during a time of extreme economic stress.

- **Data are and should be a driver.** For the Smart Circuit procurement, the project team thought the requirements related to data reporting were clear in the procurement documents. However, not all of the data expected were produced, and a lesson learned was that vendors may be sensitive about sharing data and the data requirements could have been more explicit to ensure the appropriate data were received, including defining the method and frequency of transmission. This lesson was applied successfully in the procurement of the Linden LEAP route, with a data table and transmission requirements specified in the RFP. The most critical dataset for understanding the capabilities of the technology – operator interventions – was supplied through the EasyMile API to the SCOS due to the strengthened procurement and contractual requirements. The project team did not have access to these data in the first deployment.
- **Complete autonomy may be weather-dependent and affected by other variables.** While operating in light rain, mild fog, and light snow events that were not deemed a Level 1 Snow Emergency by Franklin County seemed reasonable when developing the procurement documents based on other demonstrations in Norway and Minnesota, the reality is that most precipitation hindered the operation of the vehicles in automated mode. There are other variables, such as the exhaust from overtaking gasoline-powered vehicles in colder months, which can cause the vehicle to stop suddenly, or sun glare at certain times of the year that can cause the vehicle to slow down. These variables can have an impact on service reliability if operations are suspended or slowed. This presented more of a challenge in the initial deployment of the Linden LEAP as a transit link, but this issue was lessened when the second deployment was used for food pantry delivery. The reliability of the Smart Circuit service was not a problem during weather events, as these vehicles were able to traverse the route at normal operating speed when driven manually.

13.4. CONCLUSIONS, LESSONS LEARNED AND RECOMMENDATIONS

13.4.1. Conclusions

When deploying automated shuttles, there are many challenges, as have been described throughout this chapter. The time for a truly automated vehicle is still in the future, as the technology and sensors are not ready for every day, every-situation, Level 5 automation based on the Society of Automotive Engineers J3016 standard[122]. Refinement and enhancements need to occur to accommodate a vehicle that performs every driving task, and demonstrations such as the CEAV project can assist the development and acceleration of the technological advancements.

In conclusion, when deploying a shuttle, stakeholders should:

- **Be realistic –** Learn about the limitations of the technology and account for situations where it will not perform. For instance, weather will present significant challenges to autonomy, so if there is a daily route being serviced, other accommodations may need to be made to serve riders who rely on the operation. The manufacturers recognize this challenge and are continually refining the software package where weather events can be filtered out from the sensors and provide a more reliable operation.
- **Be flexible –** There are many variables that go into successful automation, and when encountering a limitation outside of the operational design domain, the project team needs to be flexible and make

[122] Level 5 automation is the highest classification of driving automation and is defined as a vehicle that can drive itself in all conditions with no need for a human driver.

adjustments for an overall successful deployment. These changes could be small like adjusting a station location, moderate like using a different driveway due to grade differential, or major like suspending operations during weather events or making major program changes to serve different use cases.

- **Be local –** The greatest assets for a deployment are local and in the community. It is important to create a community-based environment for a deployment to foster ownership and pride in the effort. The community was engaged in naming the shuttles and the route and had its own launch event features the robotics team from the local STEM school. EasyMile contracted EmpowerBus that was a local operator that hired local people that greeted riders and operated the shuttles. After EmpowerBus went out of business due to the pandemic, EasyMile directly hired the operators to continue the service and distribute food into the community.

Linden LEAP Spreads Good to Residents and Operators Alike

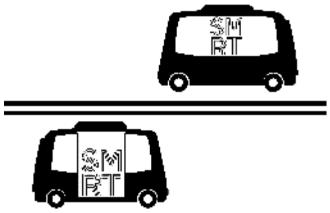
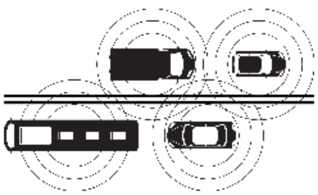
Sherri found herself without a job, coming out of a divorce, and with custody of her three beloved grandchildren. "I had no idea what I would do." Within a month she heard about the Linden LEAP Operator position through a family member who lives in Linden. **"At 10:30PM at night I submitted my application and within 24 hours I was contacted for an interview and hired. This has been such an awesome opportunity, to not only help myself, but help the community I grew up in. I'm also a licensed minister so I feel like I have a calling to serve and this is the perfect opportunity and the perfect way to be able to help. It's kinda mind blowing how you're able to prosper through something as tough as this. Because of this job I've been able to buy a new house for my grandkids and purchase a new vehicle. I am forever grateful."**

Sherri, Linden LEAP Operator, Linden

Without flexibility, the project team may not have been able to deliver a successful project in Linden due to the sudden stop incident and pandemic as confounding factors. Rethinking the mission of the vehicles, while still meeting the needs of the community allowed for a successful transformation of the deployment, despite the circumstances.

The CEAV project addressed challenges presented in the City's Smart City vision in using urban automation to solve FMLM challenges. However, the expectation to deploy in the Easton region was not met, because the proposed routes presented challenges. Ultimately, the CEAV project was able to demonstrate the technology, but in different areas of the City than originally visioned. The project addressed transportation challenges by deploying applications and strategies to meet the USDOT Vision Elements that **Table 13-9** describes.

Table 78: Connected, Electric, Autonomous Vehicles Project Relationship to USDOT Vision Elements

VISION ELEMENT #1 Urban Automation 	The CEAV project deployed two different automated shuttle routes in the City of Columbus and demonstrated how the vehicles would interact with traffic, pedestrians, and weather.
VISION ELEMENT #2 Connected Vehicle 	The Linden LEAP vehicles were connected vehicles (CVs) and transmitted the Basic Safety Message to other CVs on the roadway. This provided another example of interoperability in terms of having two different onboard units (OBUs), and an additional vehicle class that was included in the CVE project.
VISION ELEMENT #4 User-focused Mobility Services and Choices 	The CEAV project first provided a downtown circulator that offered a mobility option for those parking across the river to more easily commute into downtown from their parking area, and later provided another modal option to connect two SMHs to community services while the passenger service was still operating.
VISION ELEMENT #6 Urban Delivery and Logistics 	When the mission of the Linden LEAP shifted from passengers to food pantry boxes, the service became a targeted urban delivery service designed to address food insecurity in the community. It may be in this space that automated driving systems are truly proven and tested to achieve Level 5 automation in a relatively low risk setting.
VISION ELEMENT #7 Strategic Business Models and Partnering 	DriveOhio, The Columbus Partnership, and the City of Columbus partnered for the funding and support for the first CEAV demonstration. This was a turn-key delivery model that for future deployments could involve revenue service as part of the funding support.

VISION ELEMENT #8 Smart Grid, Roadway Electrification, and Electric Vehicles 	The six vehicles used for the Smart Circuit and the two vehicles used for the Linden LEAP were electric vehicles. The Smart Circuit vendor installed charging stations that remained after the demonstration in a public parking garage, and the Linden LEAP vendor installed outlets for charging in the St. Stephen's Community House garage that remain should St. Stephen's desire to have electric fleet vehicles.
VISION ELEMENT #10 Architecture and Standards 	Developed Intelligent Transportation Systems (ITS) architecture using Architecture Reference for Cooperative and Intelligent Transportation (ARC-IT)/ Systems Engineering Tool for Information Technology (SET-IT) for use in future deployments of CEAV. Developed Standard Operating Procedures, a Request for Proposals, a robust Test Plan, an Operational Concept, and a Deployment Playbook that can aid other agencies in the deployment of CEAV. Multiple agencies have contacted the City of Columbus for its RFP and Test Plan as they develop demonstrations of their own. This assisted the City of Columbus in its goals to help other agencies fully understand operational and safety implications, and to develop a set of automated vehicle operational testing and evaluation standards.

Source: City of Columbus

13.4.2. Lessons Learned

The lessons learned through the two CEAV projects are published on the Smart Columbus website for the Smart Circuit[123] and the Linden LEAP[124] (contained within the Deployment Playbook). Some key lessons learned at the conclusion of the project are:

- **NHTSA Route Approval is not a defined process with a defined timeline.** Depending on the complexity of the route and the adjacent facilities, such as childcare and school facilities, the review and mitigation process for receiving a NHTSA exemption may impact the deployment schedule. It is highly recommended to include a testing route submission prior to the full route submission, as it aids in maintaining the overall deployment schedule by enabling the vehicle import process to begin. It is also important to perform a review of the surrounding environment and businesses to identify and mitigate potential impacts on vulnerable populations.
- **Partner with trusted community organizations.** This will inform the outreach strategy and execution, and provide necessary third-party validation through resident engagement. While building one-on-one, authentic relationships with residents is important, partnering with long-standing, trusted community organizations to assist in identifying potential barriers to participation, developing messaging and strategy, and sharing responsibility in executing tactics provides third-party validation to the outreach work and engages more residents in the process.
- **Licensing and registration may have schedule and fee impacts.** Given the relative newness of some of the vehicle types that are being automated, the registration process can be complicated and

123 https://d3hzplpmmz6qe4.cloudfront.net/2019-07/Smart%20Columbus%20Autonomous%20Vehicle%20Lessons%20Learned_0.pdf

124 https://d2rfd3nxvhnf29.cloudfront.net/2021-05/SCC-B-CEAV-Deployment-Playbook-FINAL%2005-19-21.pdf

uncertain, as multiple agencies may need to be involved to register the vehicle for operation in the state. Also, depending on the state, a registration fee may be associated with the registration of EVs. Accounting for these fees will alleviate the need to amend the contract.

- **Complete autonomy may be weather-dependent and affected by other variables.** The vehicles did not perform as expected during precipitation events. This highlights that improvements to technology are still needed before full-time use in the real world is possible. Any near-term deployment scenario should account for weather downtime and ways to address ridership during those events. Agencies should communicate with vendors to determine the current capabilities of the vehicles. There are other variables, such as the exhaust from overtaking gasoline-powered vehicles in colder months that can cause the vehicle to stop suddenly, or sun glare at certain times of the year that can cause the vehicle to slow down.
- **Roadway geometry and cargo weight were factors that affected the final route setup.** Evaluating grade differentials at driveways and street crossings based on manufacturer specifications can reduce the risk of changes during route setup. Typically, most of the route inventory before the vehicles arrive consists of posted speeds, traffic control, and adjacent features. However, additional challenges can arise once the vehicles are on-site and other types of obstacles are identified.
- **Consider the time of year for when the route is under evaluation.** The Linden vehicles arrived in Columbus in December, and route set-up and testing took place in the winter months. As the seasons changed, emerging brush alongside the roadway posed as much influence on automation as overhead limbs. Vegetation needs to be monitored and maintained regularly for successful operation in automated mode. Regular engagement with staff that landscape trees and brush will minimize interruptions to the automated operation.
- **All AV infrastructure is not created equal** – As learned during the Smart Circuit deployment, some companies use different terminology and technology to assist the vehicle with navigating the route. While the RFP offered proposers the option to use Dedicated Short Range Communication (DSRC) Roadside Units (RSUs), May Mobility responded that it would use its own proprietary RSUs. However, these were not typical Connected Vehicle (CV) technology, but rather road-sensing units that monitor the indications of traffic signals. These units consisted of a video camera, a 4G modem, and a backup battery, and they required dedicated 120V power for operation, something that was not easily accessible in the field.

13.4.3. Recommendations

For agencies considering the deployment of CEAVs, the project team recommends:

- Clearly define what challenge or problem is being solved and why a shuttle is being deployed.
- Engage stakeholders early and often in the process, especially during the route and user needs development so there is alignment among those most vested in the deployment.
- Use community-based social outreach for directly contacting community members to systematically remove structural and other barriers to using the new technology, and encourage travel behavior change.
- Educate residents about how the technology works, including how the technology will impact them as a passenger, a pedestrian, or a driver sharing the road with an AV.
- Develop an Operational Concept to fully define the needs and goals of the project, and how it will integrate into existing operations. This will assist in developing requirements, defining what data should be collected, and testing capabilities, as well as assist in outlining any changes to the program.

- Use an RFI process to gather as much input from potential vendors as possible on the technical limitations and route constraints. This is a great opportunity to take the pulse of the industry, and see the capabilities of the technology and what flexibility the vendors can accommodate when working with an owner on the route, providing data, and testing.
- Develop a robust and specific procurement document that identifies all operating expectations and data transmission requirements (frequency as well as format). The more information provided in the RFP, the more likely the team is to get the deployment and associated information desired. This includes data requirements the vendor shall provide.
- A thorough and robust test plan can provide assurance that the vehicles will perform most functions as expected. However, even with all the scenarios contained in the test plan, it was still difficult to test for all possible situations. There could be an opportunity to conduct additional test runs during vehicle down-times. This could include more edge-case scenarios like loaded/unloaded cabin or good and bad weather. Testing could persist whenever possible due to the sensitivity of the technology and the endless combination of factors that can impact how it reacts, even if on a closed test route. It was seen that the vehicles could operate in some rain and snow, but other variables that were introduced simultaneously like wind speed and direction could affect the autonomy, and more testing would help understand the capabilities.
- Conduct a tabletop exercise with emergency responders and those closely associated with the operations, so all parties are familiar with SOPs and are prepared in the event of an incident. Also, conduct accessibility testing with the community to solicit feedback on the vehicle and procedures related to accommodating all passenger needs.
- Find a location close to the route – within 0.5 mile and preferably less than 0.25 mile – to accommodate the parking, storage, and charging (if applicable) of the vehicles for the deployment. The deadhead (the length a vehicle travels when it is not serving passengers) can impact the service schedule, as well as the range of the vehicles, and navigating on roads that are not part of the route could be a slow, manual process or potentially require travel on less-desirable, higher-speed roads.
- Identify a person or department to monitor vehicle interactions and adjust traffic control features, as necessary. It was observed that early in the Smart Circuit deployment other vehicles were overtaking the shuttle and with some targeted enforcement the activity ceased, and operations ran smoother.
- Develop a manner to communicate that the shuttle is not in service at times like inclement weather, large events affecting the route, or preplanned holidays. This could be through a website, social media, and/or signage at the station locations.

13.5. SUMMARY

The CEAV project addressed the challenges presented in the City's SCC vision in using urban automation to solve FMLM challenges. While the original award application expectation was to deploy in the Easton region, two demonstrations were completed in different areas of the city. Through these projects, the City demonstrated two different use cases: a showcase for the technology (where the Smart Circuit increased awareness and familiarity with AV technology), and FMLM challenges around connections to transit and increasing access to community services (through the Linden LEAP passenger and food pantry services). The challenges of both demonstrations indicate the time for full autonomy is still in the future, as the technology and sensors are not ready for every-day, every-situation Level 5 automation. The path to autonomy is dependent upon demonstrations such as the CEAV project, which has provided valuable data, institutional learning, and resident awareness that can assist the development and acceleration of the technological advancements. While COVID-19 was also a significant factor, the City was able to meet community needs through an alternate use case and deliver almost 130,000 meals, addressing food insecurity during a pandemic.

By creating a community-based environment for the deployments, the project team was able to foster ownership and pride in the effort. Despite the challenges encountered during the deployment, the community made the project a success. Residents relayed how the pantry service met their food needs during the pandemic and allowed them to gain some independence. The vehicle demonstrations ended with the conclusion of this project and no demonstrations within the City are known at this time, but the lessons learned and deployment playbook developed as a result of this project will aid others in the future when deployments arise.

St. Stephen's Community House Expanded Food Distribution to Hard to Reach Community Members through Linden LEAP

"Over the last year, St. Stephen's Community House has had the opportunity to reach more consumers with the extension of our Food and Nutrition Center through the Linden LEAP. With this extension, we were able to reach families that do not have reliable transportation, cannot get around on a day-to-day basis, as well as community members that were unaware of St. Stephen's services. Adding this extension was a learning experience for everyone, but one of the most important lessons that was learned was how important it is to listen to the community and adapt to their ever-changing needs. Along with listening and adapting, we can attribute the success of this program to our amazing partnerships with other organizations, like Smart Columbus, which provided additional resources, funds, and solutions."

Marilyn Mehaffie, CEO of St. Stephen's Community House

Appendix A. Acronyms

Table A. 1 contains project specific acronyms used throughout this document.

Table A. 1: Acronym List

Abbreviation/Acronym	Definition
ACOG	American College of Obstetricians and Gynecologists
ADA	Americans with Disabilities Act
ADAS	Advanced Driver Assist Systems
ADS	Automated Driving System
AEP	American Electric Power
AIM	Acceptability of Intervention Measure
ANP	Analytic Network Process
API	Application Programming Interface
APNCU	Adequacy of Prenatal Care Utilization
ARB	Architecture Review Board
ARC-IT	Architecture Reference for Cooperative and Intelligent Transportation (the National ITS reference architecture)
ATMCD	Advanced Transportation and Congestion Management Technologies Deployment
AV	Automated Vehicles
AWS	Amazon Web Services
BEV	Batter Electric Vehicle
BRT	Bus Rapid Transit
BSM	Basic Safety Messages
BSW	Blind Spot Warning
CABS	Campus Area Bus Service
CAR	Center for Automotive Research
CAV	Connected Autonomous Vehicles
CDC	Community Development Corporation
CEAV	Connected Electric Autonomous Vehicles
CES	Constant Elasticity of Substitution
CGE	Computable General Equilibrium (economic model)
CI	Continuous Integration

Abbreviation/Acronym	Definition
CMAX	COTA's Bus Rapid Transit (BRT) Service
CMCC	Connected Mobility Control Center
CMHA	Columbus Metropolitan Housing Authority
ConOps	Concept of Operations
COSI	Center for Science and Industry
COTA	Central Ohio Transit Authority
COTS	Custom Off-the-Shelf
CPS	Common Payment System
CSCC	Columbus State Community College
CTSS	Columbus Traffic Signal System
CV	Connected Vehicle
CVCP	Connected Vehicle Co-Processor (message handling software)
CVE	Connected Vehicle Environment
DATA	Deploying Automated Technologies Anywhere
DEV	Simultaneous Development of Software
DiD	Difference-in-Differences (statistical technique)
DJFS	Department of Job and Family Services
DMP	*Data Management Plan for the Smart Columbus Demonstration Program*
DoT	City's Department of Technology
DPP	*Data Privacy Plan for the Smart Columbus Demonstration Program*
DSRC	Dedicated Short Range Communications
DZA	Delivery Zone Availability
EBS	Elastic Block Store
ECB	Emergency Call Button
EEBL	Emergency Electronic Brake Light Warning
EHS	Enhanced Human Services
EPM	Event Parking Management
EPP	Enhanced Permit Parking
EST	Enhanced Smart Transportation (PTA research group)
EV	Electric Vehicle
EVSE	Electric Vehicle Supply Equipment
EVP	Emergency Vehicle Preemption (traffic signal preemption)
FCBDD	Franklin County Board of Developmental Disabilities
FCC	Federal Communications Commission

Abbreviation/Acronym	Definition
FCW	Forward Collision Warning
FMLM	First Mile/Last Mile
FMVSS	Federal Motor Vehicle Safety Standards
FSP	Freight Signal Priority
FTP	File Transfer Protocol
FY	Fiscal Year
GBFS	General Bikeshare Feed Specification
GHG	Greenhouses Gases
GIS	Geographic Information Systems
GMP	Gross Metropolitan Product
GPS	Global Positioning System
GTFS	General Transit Feed Specification
HIPAA	Health Insurance Portability and Accountability Act of 1996
HUAS	Human Use Approval Summary
IAM	Intervention Appropriateness Measure
ICD	Informed Consent Document Interface Control Document
ICT	Information and Communication Technology
IDE	Integrated Data Exchange
IEEE	Institute of Electrical and Electronics Engineers
IK	Interactive Kiosk (note that “IKE” is the brand name of the IKs used for the Smart Columbus SMHs)
IMA	Intersection Movement Assist
IoT	Internet of Things
IRB	Institutional Review Board
ITE	Institute of Transportation Engineers
ITS	Intelligent Transportation Systems
IVR	Interactive Voice Response
KPI	Key Performance Indicator
LCW	Lane Change Warning
LEAP	Linden Empowers All People (Linden automated shuttle route)
LEHD	Longitudinal Employer-Household Dynamics (US Census program)
LTE	Long-Term Evolution
MaaS	Mobility as a Service
MAP	Map Data

Abbreviation/Acronym	Definition
MAPCD	Mobility Assistance for People with Cognitive Disabilities
MCO	Managed Care Organizations
MIT	Massachusetts Institute of Technology (university)
ML	Machine Learning
MMTPA	Multimodal Trip Planning Application (the Pivot app)
MOD	Mobility on Demand
MORPC	Mid-Ohio Regional Planning Commission
MSA	Metropolitan Statistical Area
MSP	Mobility Service Provider
MVP	Minimal Viable Product
NAICS	North American Industry Classification System
NEMT	Non-emergency Medical Transportation
NHTSA	National Highway Traffic Safety Administration
NIH	National Institutes of Health
NIST	National Institute of Standards and Technology
NPRM	Notice of Proposed Rulemaking
NTP	Notice To Proceed (contract start)
OBE	Onboard Equipment
OBU	Onboard Unit
ODJFS	Ohio Department of Job and Family Services
ODM	Ohio Department of Medicaid
ODW	Logistics company involved in CVE project
ODOT	Ohio Department of Transportation
OpCon	Operational Concept
OPS	Operating Software
OS	Operating System (also known as Smart Columbus Operating System, or SCOS)
OSM	Open Street Map
OSU	The Ohio State University
OSUWMC	OSU Wexner Medical Center
OTA	Over the Air Updates
OTP	Open Trip Planner
P3	Public-Private Partnership
PCI-DSS	Payment Card Industry Data Security Standard
PfMP	Performance Measurement Plan

Abbreviation/Acronym	Definition
PHI	Protected Heath Information
PIA	Privacy Impact Assessment
PIECE	Pre-Vocational Integrated Education and Campus Experience
PII	Personally Identifiable Information
PMBOK	Project Management Book of Knowledge
PMO	Program Management Office
PMP	Project Management Plan
PNID	Personal Navigation for Individuals with Disabilities
PSID	Provider Service ID
PTA	Prenatal Trip Assistance
PUCO	Public Utilities Commission of Ohio
RCT	Randomized Controlled Trial
RDS	Relational Database Service
REST API	Representational State Transfer Application Programming Interface
RFP	Request for Proposal
RLVW	Red Light Violation Warning
RSSZ	Reduced Speed in School Zone
RSE	Roadside Equipment
RSU	Roadside Units
RTCM	Radio Technical Commission for Maritime
SASP	System Architecture and Standards Plan
SC	Smart Columbus
CA	Smart City Assessment
SCC	Smart City Challenge
SCMS	Security Credential Management System
SCODE	Smart Columbus Open Data Enthusiasts
SCOS	Smart Columbus Operating System (also known as simply OS)
SEMP	Systems Engineering Management Plan
SET-IT	Systems Engineering Tool for Information Technology (software tool)
SID	Special Improvement District
SMH	Smart Mobility Hub
SMP	Safety Management Plan
SNA	Short North Alliance (neighborhood business group)
SNMP	Simple Network Management Protocol

Abbreviation/Acronym	Definition
SOP	Standard Operating Procedures
SOV	Single-Occupancy Vehicle
SPaT	Signal Phase and Timing
SPP	Strategic Parking Plan
SRM	Signal Request Message
SSCH	St. Stephen's Community House
SSM	Signal Status Message
SSO	Single Sign On
STEM	Science Technology Engineering and Math
SyRS	System Requirement Specification
TBD	To Be Determined
TCVMS	Traffic Connected Vehicle Management System
TIM	Traveler Information Message
TMC	Traffic Management Centers
TNC	Transportation Network Company
TOC	Transportation Operations Centers
TRL	Technology Readiness Level
TSMO	Traffic Systems Maintenance Operations
TSP	Transit Signal Priority
TVIER	Transit Vehicle Interaction Event Recording
TWG	Technical Working Group
UI	User Interface
USDOE	U.S. Department of Education
USDOT	U.S. Department of Transportation
UX	User Experience
V2V	Vehicle-to-Vehicle (communications)
V2I	Vehicle-to-Infrastructure
V2X	Vehicle-to-Everything
VDTO	Vehicle Data for Transportation Operations
WIC	Women Infants and Children
WSA	Wave Service Advertisement

Source: City of Columbus

Appendix B. References

Table B. 1 includes a list of documents that can be referenced for the overall Smart Columbus program, followed by references for each of the program's eight projects.

Table B. 1: Reference Documents

Title	Description	Revision	Publication Date
Smart Columbus Program Plans			
Smart Columbus Systems Engineering Management Plan (SEMP) https://d2rfd3nxvhnf29.cloudfront.net/2019-08/Smart%20Columbus%20Systems%20Engineering%20Management%20Plan_0.pdf	Documents the Systems Engineering Plan the City of Columbus followed	Final Report	January 16, 2018
Smart Columbus Project Management Plan https://d2rfd3nxvhnf29.cloudfront.net/2021-01/SCC-A-PMP-Project%20Management%20Plan-Update-V3.pdf	Defines the principles and procedures for how the Smart Columbus Program is managed	Updated Report	January 25, 2021
Smart Columbus System Architecture and Standards Plan https://d2rfd3nxvhnf29.cloudfront.net/2021-01/SCC-B-SASP-UPDATED_V2.pdf	Documents the architecture for each of the projects	Updated Report	January 28, 2021
Smart Columbus Safety Management Plan https://d2rfd3nxvhnf29.cloudfront.net/2020-03/SCC-F-Safety%20Management%20Plan_12-05-2019_FINAL.PDF	Identifies major safety risks associated with the program and a plan to promote safety	Final Report	December 5, 2019
Smart Columbus Performance Measurement Plan https://d2rfd3nxvhnf29.cloudfront.net/2021-04/SCC-C-PfMP-Update-v3%203.30.21.pdf	Describes the outcomes of the program and how the objectives of each project relate to them	Updated Report	March 30, 2021
Performance Measures Results Link will be available at: https://smart.columbus.gov/programs/smart-city-demonstration	Documents the results of the performance measurement activities	Final Report	May 28, 2021
Smart Columbus Data Management Plan https://d2rfd3nxvhnf29.cloudfront.net/2020-08/SCC-E-DataManagementPlan-Update-v1_0.pdf	Provides operational information for the use of data within the SCOS	Updated Report	August 6, 2020

Title	Description	Revision	Publication Date
Smart Columbus Data Privacy Plan https://d2rfd3nxvhnf29.cloudfront.net/2020-09/SCC-D-DataPrivacyPlan-AnnualUpdate-V2.pdf	Provides an overarching framework for the protection of personal information in the program	Final Report	September 24, 2020
Demonstration Site Map and Installation Schedule https://d2rfd3nxvhnf29.cloudfront.net/2021-03/SCC-B-DSP%26IS-UPDATED-V2%203.8.21.pdf	Identifies the geographic area and the physical locations for all hardware elements of the program and its projects	Updated Report	March 8, 2020
Human Use Approval Summary https://d2rfd3nxvhnf29.cloudfront.net/2021-03/SCC-F-Human%20Use%20Approval%20Summary-Update-v3%20with%20attachments%203.25.21.pdf	Describes the IRB process that is applied at the program and project levels	Updated Report	March 24, 2021
Annual Safety Assessment https://d2rfd3nxvhnf29.cloudfront.net/2021-05/SCC-F-Safety%20Management%20Plan-Annual%20Safety%20Review-Final%204.9.21.pdf	Documents compliance with the Safety Management Plan	Final Report	April 9, 2021
Smart Columbus Operating System Documents			
Smart Columbus Data Management Plan https://d2rfd3nxvhnf29.cloudfront.net/2020-08/SCC-E-DataManagementPlan-Update-v1.pdf	Provides operational information for the use of data	Updated Report	August 6, 2020
Smart Columbus Data Privacy Plan https://d2rfd3nxvhnf29.cloudfront.net/2020-09/SCC-D-DataPrivacyPlan-AnnualUpdate-V2_0.pdf	Provides an overarching framework for the ways personal information will be protected	Updated Report	September 24, 2020
Smart Columbus Operating System De-Identification Policy https://d2rfd3nxvhnf29.cloudfront.net/2019-10/Smart%20Columbus%20Operating%20System%20De-Identification%20Policy.pdf	Documents the process to de-identify personal and sensitive data	Updated Report	September 17, 2019
Smart Columbus Operating Systems Operations and Maintenance Plan https://d2rfd3nxvhnf29.cloudfront.net/2020-06/SCC-B-SCOS-O%26M-Final-v1.pdf	Provides operational information for the SCOS	Final Report	January 10, 2020
Connected Vehicle Environment			
Connected Vehicle Environment Concept of Operations https://d2rfd3nxvhnf29.cloudfront.net/2021-05/SCC-B-CVE-ConOps-Update%205.14.21.pdf	Provides high-level view of the system implemented	Updated Report	May 14, 2021

Title	Description	Revision	Publication Date
Connected Vehicle Environment System Requirements https://d2rfd3nxvhnf29.cloudfront.net/2021-05/SCC-B-CVE-SyRS-UPDATE%205.20.21.PDF	Provides the requirements that drive the specification, design, development, implementation, integration and testing of the CVE	Updated Report	May 20, 2021
Connected Vehicle Environment Interface Control Document https://d2rfd3nxvhnf29.cloudfront.net/2021-05/SCC-B-CVE-ICD-UPDATE%204.4.21.pdf	Documents the necessary information required to define the interface of the CVE	Updated Report	May 4, 2021
Connected Vehicle Environment System Design Document https://d2rfd3nxvhnf29.cloudfront.net/2021-03/SCC-B-CVE-SDD-UPDATE-V1%203.10.21.pdf	Documents the design factors and the choices made to satisfy the Systems Requirements	Updated Report	March 10, 2021
Connected Vehicle Environment Test Plan https://d2rfd3nxvhnf29.cloudfront.net/2020-04/SCC-B-CVE-Test_Plan-Final.pdf	Establishes a common framework for testing elements	Final Report	April 17, 2020
Connected Vehicle Environment Operations and Maintenance Plan https://d2rfd3nxvhnf29.cloudfront.net/2021-05/SCC-B-CVE-O%26M-Final.pdf	Explains the operational and maintenance activities for the CVE	Final Report	May 27, 2021
Connected Vehicle Environment Test Report https://d2rfd3nxvhnf29.cloudfront.net/2021-05/SCC-B-CVE-Test%20Report-Final%205.5.21.pdf	Documents the results of the CVE testing	Final Report	May 5, 2021
Multimodal Trip Planning Application and Common Payment System			
Multimodal Trip Planning Application Concept of Operations https://d2rfd3nxvhnf29.cloudfront.net/2021-05/SCC-B-MMTPA-ConOps-Update%205.15.21.pdf	Conveys the high-level view of the system developed	Updated Report	May 10, 2021
Common Payment System System Requirements https://d3hzplpmmz6qe4.cloudfront.net/2019-07/Common%20Payment%20System%20System%20Requirements.pdf	Communicates the requirement to the technical community	Final Report	December 19, 2018
Multimodal Trip Planning Application Test Plan https://d2rfd3nxvhnf29.cloudfront.net/2021-03/SCC-B-MMTPA-UAT-FINAL%2010.22.20.pdf	Establishes a common framework for conducting testing activities	Final Report	October 22, 2020

Title	Description	Revision	Publication Date
Multimodal Trip Planning Application Test Report https://d2rfd3nxvhnf29.cloudfront.net/2021-03/SCC-B-MMTPA_UAT_Final_Report_20210305.pdf	Documents the results of the Pivot app testing	Final Report	March 5, 2021
Multimodal Trip Planning Application Operations and Maintenance Plan https://d2rfd3nxvhnf29.cloudfront.net/2021-03/SCC-B-MMTPA-O%26MPlan-Final%203.22.21.pdf	Explains the operational and maintenance activities for the MMTPA	Final Report	March 22, 2021
Smart Mobility Hubs			
Smart Mobility Hubs Concept of Operations https://d2rfd3nxvhnf29.cloudfront.net/2020-03/SCC-B-SMH-ConOps-Update-Final-20191224.pdf	Provides a high-level overview of the SMH	Updated Report	December 27, 2019
Smart Mobility Hubs System Requirements https://d2rfd3nxvhnf29.cloudfront.net/2021-03/SCC-B-SMH-SyRS-UPDATE-V2%203.10.21.pdf	Intended to communicate the validate set of systems requirements	Updated Report	March 10, 2021
Smart Mobility Hubs Interface Control Document https://d2rfd3nxvhnf29.cloudfront.net/2021-05/SCC-C-SMH-ICD-UPDATE%205.7.21.pdf	Defines the interface for the SMH project	Updated Report	May 7, 2021
Smart Mobility Hubs System Design Document https://d2rfd3nxvhnf29.cloudfront.net/2021-03/SCC-B-SDD-SMH-UPDATE%202.19.21.pdf	Describes the system in detail to stakeholders interested	Updated Report	February 19, 2021
Smart Mobility Hubs Master Test Plan https://d2rfd3nxvhnf29.cloudfront.net/2020-03/SCC-B-SMH-MTP-FINAL-20191011.pdf	Establishes a common framework for conducting testing activities	Final Report	October 11, 2019
Smart Mobility Hubs Test Report https://d2rfd3nxvhnf29.cloudfront.net/2020-08/SCC-B-SMH-TestReport-Final.pdf	Documents the results of the SMH testing	Final Report	August 5, 2020
Smart Mobility Hubs Operations and Maintenance Plan https://d2rfd3nxvhnf29.cloudfront.net/2021-01/SCC-B-SMH-OM-Final.pdf	Explains the operational and maintenance activities for the SMH	Final Report	August 17, 2020
Mobility Assistance for People with Cognitive Disabilities			
Mobility Assistance for People with Cognitive Disabilities Trade Study https://d3hzplpmmz6qe4.cloudfront.net/2019-07/Mobility%20Assistance%20for%20People%20with%20Cognitive%20Disabilities%20Trade%20Study.pdf	Analyze the best technical solution among a set of proposed viable solutions for the project	Final Report	March 19, 2018

Title	Description	Revision	Publication Date
Mobility Assistance for People with Cognitive Disabilities Interface Control Document https://d3hzplpmmz6qe4.cloudfront.net/2019-07/Mobility%20Assistance%20for%20People%20with%20Cognitive%20Disabilities%20Interface%20Control%20Document.pdf	Documents the information required to effectively define the systems interfaces	Final Report	July 26, 2018
Mobility Assistance for People with Cognitive Disabilities Test Plan https://d3hzplpmmz6qe4.cloudfront.net/2019-07/Mobility%20Assistance%20for%20People%20with%20Cognitive%20Disabilities%20Test%20Plan.pdf	Incorporates information regarding the integrate WayFinder system functionality	Final Report	January 18, 2019
Mobility Assistance for People with Cognitive Disabilities Test Report https://d3hzplpmmz6qe4.cloudfront.net/2019-07/Mobility%20Assistance%20for%20People%20with%20Cognitive%20Disabilities%20Test%20Report.pdf	Documents the results of the test plan	Final Report	March 27, 2019
Mobility Assistance for People with Cognitive Disabilities Operations and Maintenance Plan https://d2rfd3nxvhnf29.cloudfront.net/2021-05/SCC_B_MAPCD_Operations_And_Maintenance_Plan%2011.12.2021.pdf	Explains the operational and maintenance activities for the MAPCD	Final Report	November 1, 2019
Prenatal Trip Assistance			
Prenatal Trip Assistance Concept of Operations https://d2rfd3nxvhnf29.cloudfront.net/2021-03/SCC-B-ConOps-PTA-Update%2010.31.19.pdf	Provides a high-level view of the PTA system	Updated Report	October 31, 2020
Prenatal Trip Assistance Test Plan https://d2rfd3nxvhnf29.cloudfront.net/2021-03/SCC-B-PTA-MASTER%20TEST%20PLAN%20AND%20REPORT-FINAL-20191029.pdf	Establishes a common framework for conducting testing activities	Final Report	October 29, 2019
Prenatal Trip Assistance Operations and Maintenance Plan https://d2rfd3nxvhnf29.cloudfront.net/2021-03/SCC-B-PTA-O%26M-Final%2012.20.19.pdf	Explains operational and maintenance activities for the PTA project	Final Report	December 20, 2019
Event Parking Management			
Event Parking Management Concept of Operations https://d2rfd3nxvhnf29.cloudfront.net/2021-05/SCC-B-EPM-ConOps-UPDATE%204.30.21.pdf	Conveys a high-level view of the EPM system	Updated Report	April 30, 2021

Title	Description	Revision	Publication Date
Event Parking Management System Requirements https://d2rfd3nxvhnf29.cloudfront.net/2021-05/SCC-B-EPM-SyRS-Update%205.4.21.pdf	Communicates the requirements of the EPM system	Updated Report	May 4, 2021
Event Parking Management Test Plan https://d2rfd3nxvhnf29.cloudfront.net/2021-03/SCC-B-EPM-UAT-UPDATE.pdf	Establishes a common framework for conducting testing activities	Updated Report	March 4, 2021
Event Parking Management Test Report https://d2rfd3nxvhnf29.cloudfront.net/2021-05/SCC-B-EPM-TestReport-Final%205.11.21.pdf	Documents the results of the test plan	Final Report	May 11, 2021
Event Parking Management Operations and Maintenance Plan https://d2rfd3nxvhnf29.cloudfront.net/2021-05/SCC-B-EPM-OM%20Plan-Final-v2%202.10.21.pdf	Explains operational and maintenance activities for the EPM project	Final Report	February 10, 2021
Connected Electric Autonomous Vehicle (CEAV)			
Connected, Electric, Autonomous Vehicles Operational Concept https://d3hzplpmmz6qe4.cloudfront.net/2019-07/Smart%20Columbus%20Connected%20Electric%20Autonomous%20Vehicle%20Operational%20Concent.pdf	Describes the development of subsequent phases of the CEAV project	Final Report	March 28, 2019
Connected, Electric, Autonomous Vehicle Test Plan https://d2rfd3nxvhnf29.cloudfront.net/2021-03/SCC-CEAV%20Test%20Plan%20FINAL%2011-12-19.pdf	Documents the strategic plan for testing and criteria of acceptance	Final Report	November 12, 2019
Connected, Electric, Autonomous Vehicle Test Report https://d2rfd3nxvhnf29.cloudfront.net/2021-03/SCC-B-CEAV-Test%20Report-Final%201.4.21.pdf	Documents the results of the test plan	Final Report	January 4, 2021
Connected, Electric, Autonomous Vehicle Operational Concept – Appendix A – Alternative Use Case https://d2rfd3nxvhnf29.cloudfront.net/2020-08/SCC-B-CEAV-OpCon-APPENDIX_A-clean.pdf	Identifies use cases for the CEAV solution	N/A	May 19, 2020
Connected, Electric, Autonomous Vehicle Deployment Playbook https://d2rfd3nxvhnf29.cloudfront.net/2021-05/SCC-B-CEAV-Deployment-Playbook-FINAL%2005-19-21.pdf	Provides a framework for other agencies looking to deploy automated shuttles and documents the lessons learned from the Linden LEAP deployment	Final Report	May 19, 2021

Source: City of Columbus

THE CITY OF COLUMBUS
ANDREW J. GINTHER, MAYOR

Appendix C. Agreements

Table C. 1 provides a list of the agreements necessary to move each of the eight Smart Columbus projects from design to deployment. Note that a detailed list of agreements by project can be found in the System Architecture and Standards Plan within each project's Enterprise Architecture from the program System Architecture and Standards Plan.[125]

Table C. 1: Agreements by Project

Project	Agreements
Operating System (OS)	Ÿ Licensing Agreement Ÿ Technology Service Agreement Ÿ System Usage Agreement Ÿ Data Usage Agreement Ÿ Software Development Agreement Ÿ Employment Agreement
Connected Vehicle Environment (CVE)	Ÿ City-Traffic Connected Vehicle Management System (TCVMS) Staff Employment Agreement Ÿ RSE Supplier-TCVMS Staff Employment Agreement Ÿ COTA-Transit CV Management System Staff Employment Agreement Ÿ Brandmotion-Private Vehicle Owner Vehicle OBE Usage Agreement Ÿ City-Private Vehicle Owner Application Usage Agreement Ÿ City-Private Vehicle Owner OBE Usage Agreement Ÿ City-SCMS Provider Service Agreement Ÿ City-COTA Information Exchange Agreement Ÿ City-Public Agency Vehicle Owner OBE Usage Agreement Ÿ City-Construction Contractor Agreement for RSE Installation Ÿ City-Franklin County-Village of Obetz-ODOT-Construction Contractor Agreement for RSE Installation for County Project Ÿ City-RSE Supplier Agreement for RSE Devices Ÿ OBE Installer-OBE Installer Garages Agreement for Space Use and Installation Ÿ OBE Installer-Public Vehicle Owners/Garages Agreement for Space Use and Installation Ÿ City-Customer Relations Manager Agreement Ÿ Construction Permits

125 https://d2rfd3nxvhnf29.cloudfront.net/2021-01/SCC-B-SASP-UPDATED_V2.pdf

Project	Agreements
Multimodal Trip Planning Application (MMTPA)	Ÿ City-Kiosk Vendor Device Placement and Operations Agreement Ÿ City-MMTPA Vendor System O&M Agreement Ÿ City-Mobility Providers Information Exchange and Action Agreement Ÿ City-Mobility Providers 904 Lease Agreement Ÿ City-Traveler MMTPA Service Usage Agreement Ÿ MMTPA Vendor-Mobility Providers Non-Disclosure Agreement
Mobility Assistance for People with Cognitive Disabilities (MAPCD)	Ÿ City-MAPCD Vendor Operations & Maintenance Agreement Ÿ City-MAPCD Vendor Information Provision Data Ÿ OSU-MAPCD Vendor Information Provision Data Ÿ OSU-MAPCD Traveler Information Provision Agreement Ÿ MAPCD Vendor-MAPCD Traveler Service Usage Agreement Ÿ MAPCD Vendor-Caregiver Service Usage Agreement
Prenatal Trip Assistance (PTA)	Ÿ City-MCOs Data Sharing Agreement Ÿ OSU-MCOs Data Sharing Agreement Ÿ OSU-Prenatal Traveler Information Provision Agreement Ÿ City-MCO Reimbursement Agreement Ÿ MCO-Prenatal Traveler Service Usage Agreement Ÿ MCOs-PTA Technology Vendor Business Associate Agreement Ÿ MCOs-PTA Technology Vendor Service Agreement Ÿ NEMT Mobility Provider-Driver Service Usage Agreement Ÿ NEMT Mobility Provider-PTA Technology Vendor Service Usage Agreement
Smart Mobility Hub (SMH)	Ÿ City-SMH Facility Owners Agreement (for each facility owner) Ÿ SMH Facility Owners-Mobility Providers Shared Operations Agreement (for each facility owner and mobility provider) Ÿ SMH Facility Owners-Kiosks Vendor Device Placement and Operations Agreement (for each facility owner) Ÿ City-Experience Columbus Memorandum of Understanding (MOU) for Kiosk Provision Ÿ Experience Columbus - Kiosks Vendor Procurement Agreement Ÿ Kiosks Vendor-IK System Administrator Employment Agreement Ÿ Kiosks Vendor-Traveler Service Usage Agreement Ÿ Franklin County-ECC Operator Employment Agreement Ÿ City Permits for the Kiosk Installation
Event Parking Management (EPM)	Ÿ City-EPM Vendor O&M Agreement Ÿ City-EPM Vendor Procurement Agreement Ÿ EPM Vendor-Traveler Service Usage Agreement Ÿ EPM Vendor-Parking Facility Operator Data Provision Agreement MOU (for all participating parking facilities) Ÿ EPM Vendor-Parking Facility Operator Service Usage Agreement Ÿ EPM Vendor-Financial Institution Merchant of Record Agreement Ÿ City-Parking Operator Staff Employment Agreement Ÿ Parking Facility Operator-Parking Operator Staff Employment Agreement

Project	Agreements
Connected Electric Autonomous Vehicles (CEAV)	Ÿ CEAV Operator and CEAV Operations Staff Employment Agreement Ÿ CEAV System Operator-City Information Provision Agreement Ÿ CEAV System Operator-CEAV Operator Subconsultant Agreement Ÿ CEAV System Operator-CEAV Stop Facility Owner Agreement (for each facility) Ÿ NHTSA Federal Motor Vehicle Safety Standards (FMVSS) Exemption Ÿ Vehicle Licensure

Source: City of Columbus

Appendix D. Public Outreach Materials

To deploy a robust communications program that drives participation throughout the project lifecycle, a variety of designed pieces are necessary to clearly communicate with the wide array of applicable stakeholders. Below is a listing of materials prepared by the communications team to support project delivery from project inception through project development, project launch and project closeout.

D.1 DESIGNED MATERIALS FOR CONNECTED VEHICLE ENVIRONMENT (CVE) PROJECT

D.1.1 Billboards

- **Join the Study – Lamar**
  - Dimensions: 48x14
  - September 11, 2020

D.1.2 Digital Banner Ads

- **Join the Study – Columbus Underground**
  - Dimensions: 725x250
  - Dimensions: 728x50
  - Dimensions: 970x90
  - Dimensions: 300x250
  - Dimensions: 320x50
  - Date: October 7, 2020
- **Join the Study – NextDoor**
  - Dimensions: 1200x628
  - Date: October 20, 2020
- **Join the Study – WOSU**
  - Dimensions: 300x250
  - Date: November 13, 2020

D.1.3 Digital PPT Slide

- **Join the Study**
  - Dimensions: 13.33x7.5

D.1.4 Direct Mail

- **Join the Study**
  - Dimensions: 9x6
  - Quantity: 2.500
  - Date: August 31, 2020

D.1.5 Fact Sheets

- **1-pager – Version 1**
  - Dimensions: 8.5x11
  - Date: September 13, 2019
- **1-pager Refresh – Version 2**
  - Dimensions: 8.5x11
  - Date: July 16, 2020

D.1.6 Flyer

- **Handout - New Salem**
  - Dimensions: 8.5x11
  - Date: September 16, 2020

D.1.7 Grassroots Card

- **Join the Study**
  - Dimensions: 9x6
  - Quantity: 2,500
  - Date: November 13, 2020

D.1.8 Incentive Packet

- **Gift Card**
  - Dimensions: 2028x1272
  - Date: August 5, 2020
- **Mailer**
  - Dimensions: 8.5x11
  - Date: November 13, 2020
  - Dimensions: 8x10

D.1.9 Participation Packet

- **User Manual**
  - Dimensions: 8.5x11
  - Quantity: 1,500
  - Date: January 25, 2020
- **Wallet Card**
  - Dimensions: 3.5x2
  - Quantity: 1,500
  - Date: January 28, 2020

D.1.10 Poster

- **BrandMotion**
  - Dimensions: 24x36
  - Date: February 17, 2021
- **General Use**
  - Dimensions: 11x17
  - Date: September 10, 2020

D.1.11 Social Media Graphics

- **Facebook Carousel Ads**
  - Dimensions: 1080x1080
  - Date: January 24, 2020
- **Facebook Single Image Ads**
  - Dimensions: 1200x628
  - Date: January 24, 2020
- **Google Display Ads**
  - Dimensions: 200x200
  - Date: January 24, 2020
- **Google Display Ads**
  - Dimensions: 250x250
  - Date: January 24, 2020
- **Google Display Ads**
  - Dimensions: 300x250
  - Date: January 24, 2020
- **Google Display Ads**
  - Dimensions: 300x250
  - Date: January 24, 2020
- **Google Display Ads**
  - Dimensions: 300x600
  - Date: January 24, 2020
- **Google Display Ads**
  - Dimensions: 336x280
  - Date: January 24, 2020
- **Google Display Ads**
  - Dimensions: 728x90
  - Date: January 24, 2020
- **Instagram Landscape Ads**
  - Dimensions: 1200x628
  - Date: January 24, 2020
- **Instagram Square Ads**
  - Dimensions: 1080x1080

- Date: January 24, 2020

- **Instagram Vertical Ads**
  - Dimensions: 600x750
  - Date: January 24, 2020
- **Twitter Ads**
  - Dimensions: 600x335
  - Date: January 24, 2020

D.2 DESIGNED MATERIALS FOR PRENATAL TRIP ASSISTANCE (PTA) PROJECT

D.2.1 Crisis Communications Protocol Tool

- **Prenatal Trip Assistance (PTA) Crisis Internal Communications Protocol**
  - Dimensions: 8.5x11
  - Date: November 11, 2019

D.2.2 Project Diagram

- Dimensions: 3,001x1,690
- Date: June 4, 2018

D.2.3 Rides4Baby Branding

- **Logo Files (.JPG, .PNG and .EPS)**
  - CMYK
    - Horizontal
      - Full color
      - Reverse
      - Grayscale
      - White
    - Vertical
      - Full color
      - Reverse
      - Grayscale
      - White
  - Car Only
    - Full color
  - RGB
    - Horizontal
      - Full color
      - Reverse
      - White
    - Vertical

Full color
Reverse
White

D.2.4 Rides4Baby Brand Guidelines

- **Brand Guidelines Document**
  - Dimensions: 11x8.5
  - Date: February 25, 2019

D.2.5 Rides4Baby Application Icon

- **Rides4Baby Pink Icon**
  - Dimensions: 738x758
  - Date: February 20, 2019

D.2.6 Rides4Baby Application Guides

- **Mobile Application Admin Guide**
  - Dimensions: 8.5x11
  - Date: May 28, 2019
- **Mobile Application User Guide**
  - Dimensions: 8.5x11
  - Date: May 28, 2019

D.2.7 Rides4Baby Welcome Packets

- **Welcome Letter**
  - Dimensions: 8.5x11
  - Date: May 28, 2019
- **Wallet Card (3 versions–CareSource, Molina and intervention group)**
  - Dimensions: 3.5x2
  - Date: October 30, 2019
- **Benefits Sheet**
  - Dimensions: 8.5x11
  - Date: May 28, 2019
- **Materials Request Form**
  - Dimensions: 8.5x11
  - Date: June 25, 2019
- **Outreach Tips Sheet**
  - Dimensions: 8.5x11
  - Date: June 18, 2019

D.2.8 Rides4Baby Table Tents

- **Table Tents (3 versions)**
  - Dimensions: 8.5x11
  - Date: May 16, 2019

D.2.9 Rides4Baby T-shirts

- **Table Tents (2 versions)**
  - Dimensions: 9x4.8743
  - Date: February 18, 2019

D.2.10 Half-Letter Cards (StepOne)

- **Round 1**
  - Dimensions: 5.5x8.5
  - Date: May 24, 2019
  - Round 2
  - Dimensions: 5.5x8.5
  - Date: July 23, 2019

D.2.11 Tip Cards

- **Getting the most out of your no-cost transportation benefits? (Rides4Baby)**
  - Dimensions: 2x3.5
  - Quantity: N/A
  - Date: October 18, 2018
- **Getting the most out of your no-cost transportation benefits? (StepOne)**
  - Dimensions: 2x3.5
  - Quantity: N/A
  - Date: September 19, 2019

D.2.12 COTA Bus Advertisements

- **Getting the most out of your no-cost transportation benefits?**
  - Dimensions: 28x11
  - Date: January 22, 2020

D.2.13 Grievances Card and Envelope (Rides4Baby)

- **Blank card with Rides4Baby Logo**
  - Dimensions: 4.875x3.625 (folded in half)
  - Quantity: 2000
  - Date: May 3, 2019
- **A1 Envelopes with Square Flaps**
  - Dimensions: 5.125x3.625
  - Quantity: 2000
  - Date: May 3, 2019

D.2.14 CareSource Eblast

- **Eblast copy and graphics**
  - Date: June 4, 2019

D.2.15 Church Presentation Slides

- **Standard (4:3)**
  - Dimensions: 10x7.5
  - Date: April 30, 2019
- **Widescreen (16:9)**
  - Dimensions: 10x5.625
  - Date: April 30, 2019

D.2.16 City of Columbus Website Graphics

- **Callout**
  - Dimensions: 3335x1288 (300ppi)
  - Date: May 5, 2019
- **Header**
  - Dimensions: 1596x485 (300ppi)
  - Date: May 5, 2019
- **Partner Logos Lockup**
  - Dimensions: 3335x1197 (300ppi)
  - Date: May 5, 2019

D.2.17 Digital Advertisements

- **Round 1 – Call StepOne Today**
  - Dimensions:
    - Facebook – 1200x1200
    - Google Display – 300x250
    - Google Display – 350x50
    - Instagram – 1080x1080
    - Run on Network – 160x600
    - Run on Network – 728x90
    - Run on Network – 800x800
    - Run on Network – 970x90
    - Twitter – 600x335
  - Date: June 24, 2019
- **Round 2 – Call Today**
  - Dimensions:
    - Facebook – 1200x1200
    - Google Display – 300x250
    - Google Display – 350x50
    - Instagram – 1080x1080

        - Run on Network – 160x600
        - Run on Network – 728x90
        - Run on Network – 800x800
        - Run on Network – 970x90
        - Twitter – 600x335
    - Date: September 27, 2019

- **Round 3 – Click for a chance to earn up to $140**
    - Dimensions:
        - Facebook – 1200x1200
        - Google Display – 300x250
        - Google Display – 350x50
        - Instagram – 1080x1080
        - Run on Network – 160x600
        - Run on Network – 728x90
        - Run on Network – 800x800
        - Run on Network – 970x90
        - Twitter – 600x335
    - Date: September 27, 2019

D.2.18 Smart Columbus Prenatal Trip Assistance Community Partner Information Session (June 25, 2019)

- **Invitation**
    - Dimensions: 8.5x11
    - Date: May 23, 2019
- **Google Survey Graphics**
    - Header
        - Dimensions: 6668x1668
        - Date: May 22, 2019
    - Callout
        - Dimensions: 1601x401
        - Date: May 22, 2019
- **Presentation (PowerPoint)**
    - Widescreen (16:9)
        - Dimensions: 10x5.625
        - Date: June 6, 2019

D.2.19 Flyers with Contact Strips

- **Round 1 – StepOne**
    - Dimensions: 8.5x11
    - Date: July 24, 2019
- **Round 2 – Rides4Baby**
    - Dimensions: 8.5x11
    - Date: November 11, 2019

D.2.20 Hang Tag for Incentive Jar

- **Help Us Recruit Patients to Rides4Baby**
  - Dimensions: 4.75x6.75
  - Date: May 28, 2019

D.2.21 MCO Flyers (CelebrateOne)

- **Round 1 – You're Invited! Pregnant?**
  - Dimensions: 8.5x11
  - Date: May 31, 2019
- **Round 2 – You're Invited! Pregnant?**
  - Dimensions: 8.5x11
  - Date: July 24, 2019

D.2.22 MCO Invitations (CelebrateOne)

- **CareSource**
  - Card – You're Invited! Pregnant?
    - Dimensions: 5x7
    - Date: January 27, 2020
  - A7 Envelope
    - Dimensions: 5.25x7.25
    - Date: January 27, 2020
- **Molina**
  - Card – You're Invited! Pregnant?
    - Dimensions: 5x7
    - Date: January 30, 2020
  - A7 Envelope
    - Dimensions: 5.25x7.25
    - Date: January 30, 2020

D.2.23 Poster with Contact Strips

- **Pregnant?**
  - Dimensions: 11x17
  - Date: July 25, 2019

D.2.24 Print Advertisements

- **African American News Journal – Pregnant?**
  - Dimensions: 5x7
  - Date: April 30, 2019
- **African American Columbus Minority Communicator Newspaper – Pregnant?**
  - Dimensions: 5x7
  - Date: July 23, 2019

D.2.25 Social Media

- **Round 1 – Call StepOne today**
  - Facebook (8 versions)
    - Dimensions: 1200x630
    - Date: June 19, 2019
  - Instagram (6 versions)
    - Dimensions: 1080x1080
    - Date: June 19, 2019
  - Twitter (6 versions)
    - Dimensions: 506x253
    - Date: June 19, 2019
- **Round 2 – Call today**
  - Facebook (8 versions)
    - Dimensions: 1200x630
    - Date: September 30, 2019
  - Instagram (6 versions)
    - Dimensions: 1080x1080
    - Date: September 30, 2019
  - Twitter (6 versions)
    - Dimensions: 506x253
    - Date: September 30, 2019
- **Round 3 – Earn up to $140**
  - Facebook (1 version)
    - Dimensions: 1200x630
    - Date: October 1, 2019
  - Instagram (1 version)
    - Dimensions: 1080x1080
    - Date: October 1, 2019
  - Twitter (1 version)
    - Dimensions: 506x253
    - Date: October 1, 2019

D.2.26 Television Advertisement (CTV)

- **Getting the most out of your no-cost transportation benefits?**
  - Dimensions: 1920x1080 (72ppi)
  - Date: September 13, 2019

D.2.27 Wallet Card (double-sided)

- **Get connected with care or other pregnancy related resources / Getting the most out of your no-cost transportation benefits?**
  - Dimensions: 2x3.5
  - Date: January 7, 2020

D.3 DESIGNED MATERIALS FOR EVENT PARKING MANAGEMENT (EPM) PROJECT

D.3.1 Digital Ads

- **Columbus Underground: Holiday Promo**
  - Email Banner
    - Dimensions: 300x250
    - Date: November 6, 2020
  - Email Banner
    - Dimensions: 728x90
    - Date: November 6, 2020
  - Twitter Banner
    - Dimensions: 1080x1080
    - Date: November 6, 2020
- **Columbus Underground: Super Leaderboards**
  - Dimensions: 320x50
  - Dimensions: 728x90
  - Dimensions: 970x90
  - Date: November 6, 2020
- **Experience Columbus: Instagram Story (5 Slides)**
  - Dimensions: 1920x1080
  - Date: January 26, 2021
- **Next Door**
  - Dimensions: 1200x628
  - Date: March 8, 2021 (Round 1)
  - Date: March 24, 2021 (Round 2)

D.3.2 Garage Poster

- Dimensions: 8.5x11
- Printed: 30
- Date: February 24, 2021

D.3.3 IKE Ads

- **Horizontal Version**
  - Dimensions: 1920x1080
  - Date: January 18, 2021
- **Vertical Version**
  - Dimensions: 1080x1920
  - Date: January 18, 2021

D.3.4 Parking Meter Hanger

- Dimensions: 9x12
- Printed: 300
- Date: January 25, 2021

D.3.5 SMRT Web

- Dimensions: 1024x768
- Date: November 5, 2020

D.3.6 Social Media

- **Facebook: Take Our Survey (8 images)**
  - Dimensions: 1080x1080
  - Date: September 20, 2020
- **Facebook: Take Our Survey (4 images)**
  - Dimensions: 600x750
  - Date: September 20, 2020
- **Facebook: Take Our 8 images)**
  - Dimensions: 1200x628
  - Date: September 20, 2020
- **Facebook: Holiday Promo (5 images)**
  - Dimensions: 1080x1080
  - Date: November 5, 2020
- **Facebook: Download the App (2 images)**
  - Dimensions: 1080x1080
  - Date: November 5, 2020
- **Instagram: Download the App (2 images)**
  - Dimensions: 1080x1080
  - Date: November 5, 2020
- **Twitter: Holiday Promo (5 images)**
  - Dimensions: 1200x675
  - Date: October 19, 2020

D.3.7 Web App

- **Facebook**
  - Dimensions: 1080x1080
  - Date: February 1, 2021
- **Instagram**
  - Dimensions: 1080x1080
  - Date: February 1, 2021
- **Twitter**

- Dimensions: 1080x1080
- Date: February 1, 2021

D.4 DESIGNED MATERIALS FOR CONNECTED ELECTRIC AUTONOMOUS VEHICLES (CEAV)

D.4.1 Direct Mail

- **The Linden LEAP is Coming**
  - Dimensions: 9x6
  - Quantity: 4,196
  - Date: January 15, 2020

D.4.2 Door Hanger

- **Ride the Linden LEAP**
  - Dimensions: 4x9
  - Quantity: 1,500
  - Date: January 27, 2020

D.4.3 Fact Sheets

- **The Linden LEAP – Version 1**
  - Dimensions: 8.5x11
  - Date: February 20, 2020
- **The New Linden LEAP – Version 2**
  - Dimensions: 8.5x11
  - Date: August 24, 2020

D.4.4 Hot Card

- **Help Shape the Future**
  - Dimensions: 6x11
  - Quantity: 2,500
  - Date: September 17, 2020

D.4.5 IKE Kiosk

- **The New Linden LEAP – Vertical**
  - Dimensions: 1080x1920
  - Date: September 16, 2020
- **The New Linden LEAP – Horizontal**
  - Dimensions: 1920x1080
  - Date: September 16, 2020

D.4.6 LEAP Community Launch Event

- **Event Passport**
  - Dimensions: 6x4.25
  - Date: February 13, 2020
- **Linden Advertisement (CE/AV)**
  - Dimensions: 8x10
  - Date: June 2020
- **Promotional Flyer**
  - Dimensions: 8.5x11
  - Date: February 11, 2020

D.4.7 Linden Advertisements – Additional

- **June 2020 (CVE/SMH)**
  - Dimensions: 8x10
- **August 2020**
  - Dimensions: 8x10
- **September 2020**
  - Dimensions: 8x10
- **October 2020**
  - Dimensions: 8x10
- **November 2020**
  - Dimensions: 8x10

D.4.8 Mailer

- **Ride the Linden LEAP**
  - Dimensions: 8.5x11
  - Date: January 31, 2020

D.4.9 Rosewind Estates Flyer

- **Linden LEAP Returns July 30**
  - Dimensions: 8.5x11
  - Date: July 28, 2020
- **Linden LEAP Closeout**
  - Dimensions: 8.5x11
  - Date: April 1, 2021

D.4.10 Route Map

- **Linden LEAP route map**

D.4.11 Route Stop Poster

- **Ride the Linden LEAP**
  - Dimensions: 11x17
  - Date: February 24, 2020

D.4.12 Sandwich Board

- **The LEAP is currently out of service/Take Our Survey**
  - Dimensions: 24x36
  - Date: November 13, 2020

D.4.13 Survey Card

- **Take Our Survey**
  - Dimensions: 24x36
  - Dates:
    - February 14, 2020
    - July 6, 2020
    - September 16, 2020
    - December 9, 2020

D.4.14 Website Graphics

- **Linden LEAP Relaunches**
  - Dimensions: 1024x768
  - Date: October 13, 2020

D.5 DESIGNED MATERIALS FOR SMART MOBILITY HUBS (SMH) PROJECT

D.5.1 Digital Ads

- **Radio One Banner Ad**
  - Dimensions: 300x250
  - Date: April 13, 2021
- **Next Door**
  - Dimensions: 1200x628
  - Date: April 12, 2021
- **Smart Mobility Hub Display Ads**
  - Dimensions: 300x250
  - Dimensions: 728x90
  - Dimensions: 320x50
  - Dimensions: 300x600
  - Dimensions: 300x250
  - Date: July 23, 2020

D.5.2 Videos (shot at six locations)

- **St. Stephen's Community House**
- **Northern Lights**
- **Linden Library**
- **Linden Transit Center**
- **Easton Transit Center**
- **Columbus State Community College**

D.5.3 Photography (shot at six locations)

- **St. Stephen's Community House**
- **Northern Lights**
- **Linden Library**
- **Linden Transit Center**
- **Easton Transit Center**
- **Columbus State Community College**

D.5.4 Website Header Images and About Page

- **Two images for each page with branding elements**

D.6 DESIGNED MATERIALS FOR MULTIMODAL TRIP PLANNING APPLICATION (MMTPA) PROJECT

D.6.1 Digital Graphics

- **Email Banner**
  - Dimensions: 600x100
- **Facebook**
  - Dimensions: 1200x628
  - Dimensions: 1080x1080
- **Instagram**
  - Dimensions: 1200x628
  - Dimensions: 1080x1080
  - Dimensions: 600x750
- **Twitter**
  - Dimensions: 600x335
  - Dimensions: 800x418
- **Google Display**
  - Dimensions: 200x200
  - Dimensions: 250x250
  - Dimensions: 300x250
  - Dimensions: 300x600
  - Dimensions: 336x280
  - Dimensions: 728x90

D.6.2 Additional Digital Ads

- **Banner Ads for Urban One/CD 92.9/WOSU/Columbus Underground/La Mega**
  - Dimensions: 300x250
    - Date: April 20, 2021
  - Dimensions: 300x250
  - Dimensions: 728x90 (2)
  - Dimensions: 728x250
  - Dimensions: 300x600 (2)
  - Dimensions: 320x50 (2)
  - Dimensions: 468x60
    - Date: February 4, 2020
  - Dimensions: 300x250
    - Date: February 3, 2020
  - Dimensions: 790x 90
  - Dimensions: 970x90 (2)
    - Date: November 2, 2020
- **Next Door Ad**
  - Dimensions: 1200x628
    - Date April 12, 2021

D.6.3 Additional Social Media Graphics

- **Facebook and Instagram images for Urban One/CD 92.9/La Mega**
  - Dimensions: 1200x628 (8 images)
    - Date: February 10, 2021
  - Dimensions: 1200x628(4 images)
  - Dimensions: 800x800 (12 images)
    - Date: November 9, 2020
- **Mobility Partner Instagram Ads (x9)**
  - Dimensions: 1080x1080
    - Date: November 5, 2020
- **Mobility Partner Facebook Ads (x9)**
  - Dimensions: 1200x628
    - Date: November 5, 2020

D.6.4 Additional Print Materials

- **Columbus African American News Journal Ads**
  - Dimensions: 10.25” x 14.5”
    - Dates: January 28, 2021
    - Dates: March 12, 2021
- **Columbus African American News Journal Ad**
  - Dimensions: 10.25” x 8.25

        - Date: November 17, 2020

- **La Mega Ad**
    - Dimensions: 9.7” x 10”
        - Date: February 18, 2021
- **Bumper Sticker**
    - Dimensions: 6” Oval
        - Date: February 5, 2021
- **Postcard**
    - Dimensions: 4” x 6”
        - Date: April 22, 2021
- **Business Card**
    - Dimensions: 2” x 3.5”
        - Date: November 11, 2020
- **Toolkit: Grandview and Linden Talking Points & FAQ Flyers**
    - Dimensions: 8.5” x 11”
    - Date: July 2, 2020

Appendix E. Program Results from The Ohio State University

The Ohio State University (OSU) has conducted economic, accessibility and housing analyses as part of the Smart City Challenge. **Section E.1** discusses economic analysis study which shows that Smart Columbus projects generate both short-run and long-run impacts on the local economy. The accessibility analysis discussed in **Section E.2** is focused on the Linden neighborhood within the study region of the CMAX corridor and the intent of Smart Columbus is to improve ladders of opportunity within the community dovetails precisely with this perspective on transportation system performance and its value to a community. Housing market analysis conducted in the Linden neighborhood along with the improvements provided by SMHs is described in **Section E.3**.

E.1 ECONOMIC IMPACT OF SMART CITY INVESTMENT: EVIDENCE FROM THE SMART COLUMBUS PROJECTS

E.1.1 Authors

Zhenhua Chen and Junmei Cheng, City and Regional Planning, The Ohio State University.

E.1.2 Abstract

Smart city initiatives, as a new urban planning strategy, have received increasing attention in recent years worldwide. While many studies have investigated the fundamentals of smart cities, there is still a lack of understanding of the economic impact of smart cities, especially from the real-world practical perspective. This study addresses this issue by developing an assessment framework of the economic impact of smart city investment using a computable general equilibrium (CGE) model. The Smart Columbus Program was adopted as a case study for the assessment. The analysis shows that Smart Columbus projects generate both short-run and long-run impacts on the local economy. Specifically, the short-run impact was generated through the investment in factor inputs of related sectors, such as transportation, information, and communication, during its implementation stage. The long-run impact was primarily achieved through the changes in productivity of urban transportation sectors and the demand for mobility services. Overall, the research provides a useful assessment tool for the economic impact assessment of smart city investment. It also improves the understanding of the economic benefits of a smart city strategy, which may provide implications for future investment decision-making both in Columbus and other cities.

Keywords: Smart City, economic impact, Computable General Equilibrium Model, Connected Vehicle Environment, Automated Vehicles, Mobility

E.1.3 Introduction

The world is facing increasing challenges, such as traffic congestion, climate change, and social disparity, especially during the process of urbanization. As an innovative strategy to achieve the goals of safe, intelligent and sustainable development , smart city concepts have received increasing attention from different stakeholders, including private investors and governments, given the rapid development of information and communication technologies. Many scholars also believe that the development of smart technologies through infrastructure investment may provide effective solutions to various challenges (Tan & Taeihagh, 2020). In December 2015, the U.S. Department of Transportation

(USDOT) launched the Smart City Challenge, an initiative focusing on smart city development to solve modern city challenges with an emphasis on transportation problems, such as traffic congestion, parking inefficiency, first mile/last mile challenge, transport data coordination, and reducing carbon emissions (USDOT, 2016). The initiative received applications from 78 U.S. cities. Columbus was selected as the winner, given it provided a holistic vision on smart city development with a focus on addressing the challenges that various communities face using novel technologies, such as connected infrastructure and automated vehicles (AV). With the support of $40 million from USDOT and $10 million from the Paul G. Allen Family Foundation, Columbus launched the “Smart Columbus” initiative to facilitate smart city development with a focus on the following four main areas: connected transportation network, electric vehicle infrastructure, integrated data exchange, and enhanced human services. The initiative was expected to drive economic growth, improve the quality of life, foster sustainability, and improve roadway safety.

The objective of this research is to evaluate the economic impact of the Smart Columbus Program. The initial investment of the program focuses on developing a pilot program and demonstration for smart technology applications. While the infrastructure investment may generate a short-run economic impact through the increase of local public capital expenditure during the project development stage, it should be noted that a successfully deployed system is expected to have a long-run impact on the economy if the applications and adoption of smart technologies could lead to a large scale of behavioral change of urban mobility.

To provide a comprehensive understanding of the economic impact of the Smart Columbus Program, the study develops a comprehensive evaluation framework for the impact assessment of smart city-related investment. The analysis involves both a short-run and long-run impact assessment using a CGE model. In addition, the economic impact of infrastructure investment in different Smart Columbus projects was compared. In the end, the implications for future smart city infrastructure development are discussed.

The **Section E.1** is organized as follows. **Section E.1.4** provides a review of the literature. **Section E.1.5** introduces Smart Columbus projects. **Section E.1.6** presents methods and data. **Section E.1.7** discusses the results, whereas **Section E.1.8** concludes and summarizes.

E.1.4 Literature Review

To gain a thorough understanding of the smart city development and its economic impact, the following literature review focuses on the fundamentals of smart city, which includes concept, characteristics, and dimension, economic effects, and evaluation methods. The research gaps are summarized at the end of the section.

E.1.4.1 THE FUNDAMENTALS OF SMART CITY

Concept

The rapid technology development has facilitated the development of the smart city in many countries to address various challenges that the world faces, as shown in **Table E-13**. The interest in the smart city is also on the rise in the academic field. While extensive studies, such as (Nam & Pardo, 2011), (Albino et al., 2015)), Monzon (2015), (Lara et al., 2016)), Tan and Taeihagh (2020), and Clark (2020) have attempted to provide definitions of smart city, the concept essentially could be summarized in the following three aspects. First, a few studies indicated that smart city addresses the application of advanced technologies, such as internet of things (IoT), information and communication technology (ICT), and big data processing technology (Lara et al., 2016). Second, there is a general consensus that the implementation of a smart city must be supported by non-technological developments in areas such as socioeconomic status, human capital, and regulation (Tan & Taeihagh, 2020). Third, infrastructure is considered to have a pivotal role in providing essential smart services through materialized technology during a smart city development ((Nam & Pardo, 2011). Lastly, the smart city is targeted to solve urban problems, and the objectives of smart city generally focus on aspects such as promoting economic growth, improving the quality of life, facilitating social justice, and creating resilient and sustainable socioeconomic environments (Clark, 2020; Tan & Taeihagh, 2020). In sum, a smart city initiative can be defined as the application of advanced ICT technologies to the development and operation of critical infrastructure to achieve an efficient, equitable, resilient, and sustainable city.

Table E. 1: Examples of Smart City Initiatives Implemented among Different World Cities

ID	City	Name of Initiative	Year of Implementation	Investment Amount	Major Deployed Smart Technologies
1	Singapore	Smart Nation	2014	$1.7 billion	Information and communications technology (ICT), AVs, cashless payments, robots
2	Hong Kong	Smart City Blueprint for Hong Kong	2017	$300 million	Multi-functional smart lamppost, smart lock for cargo, wearable tech for prisoners, open data dashboard, mobile-enabled digital id, digital departure, digital twin for smart cities
3	London	Smart London	2013	$598 million	Artificial intelligence and machine learning, virtual reality and augmented reality, sensors, 5g networks, internet of things, computers making decisions using algorithms, and smart mobility
4	Dubai	Smart Dubai	2015	$8 billion	Blockchain, artificial intelligence, data science, machine learning, and the internet of things
5	Shenzhen	New Smart City	2018	$77.24 million	Internet of things, big data, cloud computing, mobile internet, artificial intelligence
6	Columbus, Ohio	Smart Columbus	2016	$54.6 million	Internet of things, connected vehicle environment, and self-driving shuttles

Source: Authors' Collection

Characteristics

As summarized by (Caragliu et al., 2011), a smart city has the following six characteristics: (1) it generally consists of a networked infrastructure with increased efficiency of service than conventional infrastructure system, which is often isolated. The connected infrastructure is more likely to promote urban development at a wider geographic scale through spatial spillover effects; (2) smart city emphasize business-driven development since it tends to generate more dynamic and viable socioeconomic performance; (3) it emphasizes citizen's participation and involvement in public service; (4) high-tech and innovative industries could play an even more crucial role in the long-term growth of the city; (5) more attention should be paid to the issue of polarization in the economy, culture, and geography; and (6) sustainability is a critical component of the smart city given the concern of scarcity of resources. Unlike conventional urban development initiatives, the concept of smart city concerns not only economic development, it also emphasizes social equity and sustainability. In addition, the crux of a smart city is to achieve these objectives through a series of strategies, including the development of networked infrastructure, the adoption of high technology, and the promotion of innovation in the development of a future city.

Dimensions

The dimensions of a smart city generally include the following aspects: economy, people, governance, mobility, environment, and living (Lombardi et al., 2012). The smart is displayed in separated features of urban life rather than in a holistic way. Specifically, a smart economy focuses on improving industrial development, income, and employment. Smart governance addresses democracy and citizen participation in policymaking. Smart mobility concentrates on developing advanced and connected logistics and infrastructure. A smart environment pursues sustainable development of resources. Smart living aims to improve the quality of life through the implementation of advanced technologies. The smart city is achieved by applying advanced technologies such as IoT and big data processing technology, concepts such as sustainability and democracy, and initiatives such as AVs in these dimensions of a city. In addition, (Nam & Pardo, 2011) indicated that a smart city consists of the following three key factors: technology, people, and community. A technology factor refers to the planning for physical infrastructure and applications of advanced technologies. A human factor consists of education, creativity, and social learning. Institutional factor comprises of administrative environments, such as democracy, citizen participation in decision-making, and involvement of disadvantaged groups. In sum, the smart city embodies various aspects of urban life, which is a combination of multiple smart systems rather than a holistic item.

E.1.4.2 THE ECONOMIC EFFECTS OF SMART CITY DEVELOPMENT

Economic Effects

The economic effects of the smart city include both short-run effects and long-run effects. In the short run, the investment in smart technology and infrastructure provides a stimulus to the local economy through the increase in capital and labor expenditure. For example, (Terry & Bachmann, 2019) studied the short-run impact of AV on the finances of four types of governments, including the federal government, four provincial governments, two regional governments, and one municipal government in Canada by revenue and expense analysis. Government revenues include gas tax, driver’s licenses, vehicle registration fees, traffic ticket fines, and parking fees, while expenses include roadside conduits, signal upgrades, road repaving and repainting, and parking maintenance. Their analysis showed that these revenues were minimal or even negative while the expenses on upgrading infrastructures were relatively high, especially for the municipal government, which accounts for about 30% of single-year revenue. In the long run, smart city investment is likely to generate additional economic impacts if a large scale of behavioral responses was achieved due to the successfully deployed technology and infrastructure. For instance, (Kim et al., 2016) classified 30 industries related to smart cities and estimated the induced effects of these industries on the national economy by improvement in productivity, employment, and added value using the input-output analysis, which showed that the induction coefficients of the smart city industry on productivity, employment, and added value are 1.975, 6.015, and 0.6541, respectively. It is found that smart city-related sectors, such as information and communication technologies, and related service industries, such as retail trade and technical activities, played a significant role in economic growth and sustainable development. However, it remains unclear how the economic impact was achieved through the smart city investment, given the inherent impact mechanism was not fully disclosed.

The economic effects of the smart city have also been evaluated from various aspects. Most studies attempted to evaluate the economic impact of smart cities with a focus on specific smart technologies, such as AV, battery electric vehicles (BEV), and smart streetlighting systems. For instance, (Clements & Kockelman, 2017) evaluated the economic effects of AVs in the U.S. and found that AVs could generate an economic benefit of $1.2 trillion or $3,800 per American each year. Similarly, (Ongel et al., 2019) assessed the total cost of ownership of AVs, which showed that the total cost of AVs reduced 60% -75% compared to that of conventional vehicles. Moreover, Chen et al. (2021) investigated both the environmental and economic impact of BEVs by their three drives of costs, including subsidies, incentives, and fuel price using the CGE model, which showed that subsidies have more considerable economic impact compared with the other two drivers and that the environmental impact was not significant. In addition, the economic benefits of the LED streetlighting system, which is one type of smart infrastructure launched in Europe, were evaluated using cost-benefit analysis using three indicators: net profit, net discounted savings, and total savings (Strielkowski et al., 2020). This study showed that LED streetlighting systems could generate 50 million EUR (euros) in energy and electricity savings in two or three years.

In addition, some studies have also provided a more holistic assessment of the economic impact of smart city development with a focus on multiple aspects of the urban systems. For instance, (Neirotti et al., 2014) evaluated the economic performance of smart cities with a focus on the following systems, including natural resources, energy, transportation mobility, buildings, living quality, government, economy, and people. The economic performance measured by Gross Domestic Product (GDP) and the unemployment rate was used to explain if smart practices were covered in each domain using the factor analysis. It was found that there was no significant relationship between economic performance and the adoption of smart practices. Similarly, (Yadav et al., 2019) grouped three levels and a total of 31 enablers of a sustainable smart city and applied them as indicators to measure smart city performance using the hybrid BWM-ISM approach[126]. It was found that information and communication technologies, innovative construction technologies, and supporting government policies act as important drivers of smart cities. Although these studies provided an economic impact assessment of smart cities in a holistic view, they were based on hypothesized scenarios while empirical practices remain scant. In addition, it is important to understand the domains of a smart city and what specific practices this smart city has implemented since different cities might have varied categories.

Assessment Approach

In terms of the approach for smart city project evaluation, extensive studies measured the performance of smart city development based on various indicators, although different typological methods were used to organize these indicators (Sharifi, 2019). For example, (Angelakoglou et al., 2019) introduced a framework including six steps to determine key performance indicators (KPIs) of smart city solutions. A collection of 75 KPIs in six dimensions, including technical, economic, environmental, social, ICT and legal KPIs was constructed. Moreover, Shen et al. (2018) adopted the entropy method based on the following selected indicators to determine the weight of indicators and using the TOPSIS[127] approach to evaluate performance. It was concluded that smart city performance in China was not good and unbalanced among five dimensions, including economy, environment, people, infrastructure, and governance. Similarly, (Lombardi et al., 2012) combined indicators, the triple helix model, and the analytic network process (ANP) method to measure smart city performances. In addition, (Dameri, 2017) presented a smart city theoretical framework called Smart City Dashboard to measure smart city performance in five steps: (1) define smart city value chain, (2) select indicators, (3) build the smartness dashboard, (4) implement the dashboard, and (5) scalability and sustainability analysis of the dashboard.

However, there are a few critical issues with the indicator approach. First, it is always challenging to secure the validity of indicators. In general, the criteria of evaluation should be established first before the selection of indicators. For example, Sharifi (2019) developed a framework to assess smart city assessment tools based on multiple evaluation criteria such as comprehensive, flexibility and feasibility. 34 smart city assessment tools were evaluated in terms of their weaknesses and strengths. It was found that most tools are constituted by indicators, but there is a lack of assessment tools that are based on more complex modeling methods and scenarios. Second, whether standardized indicators are needed is debatable (Caird & Hallett, 2019). On the one hand, standardization may facilitate the performance evaluation and

[126] Best Worst Method (BWM) – Interpretive Structural Modelling (ISM)

[127] Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS)

comparison across cities. On the other hand, the effectiveness of standardized indicators could be questionable unless they are appropriately adapted with clear distinctions of the characteristics of smart cities.

E.1.4.3 RESEARCH GAP

Overall, while extensive studies have attempted to provide an understanding of the smart city fundamentals, there are a few research gaps in smart city assessment. First, although many studies have developed various smart city assessment tools, most of them focused on the evaluation of the overall technological performance, whereas there is a lack of assessment from the perspective of economic impacts of the deployed systems. It is also unclear what the inherent mechanism between a smart city initiative and the economic performance is. Second, previous assessments of smart cities mainly relied on the indicator approach, which has several major limitations, such as the involvement of subjectivity in terms of the indicator selection, and that the indicators could only be applied in limited cases. Hence, it becomes imperative to develop a comprehensive assessment tool to quantify the impact of smart city-related investment and initiatives accurately. Third, while many studies have attempted to understand the impact of smart city initiatives from qualitative and theoretical perspectives, there is still a lack of empirical understanding of the economic impact of smart cities, especially based on the case of real-world development.

E.1.5 Smart Columbus Program

The Smart Columbus Program was developed to address the following major mobility challenges that the Columbus metropolitan area encountered. First, although the regional population keeps expanding constantly, there is still a lack of transportation options for different social groups, especially for the vulnerable groups, such as people with disabilities, pregnant individuals, and the elderly population. Second, the spatial distribution of transportation services is quite uneven in Columbus. In particular, many low-income communities still face the first mile/last mile challenge. Third, parking can be a nightmare due to the lack of parking facilities and valid and real-time parking information.

In order to address these challenges, the Smart Columbus Program included eight projects with the support of the Smart City Challenge funds from USDOT. The Smart Columbus Operating System (SCOS), as the backbone of the Smart Columbus Program, provides support to other Smart Columbus projects. In particular, the Smart Columbus projects were classified into three areas (as shown in **Figure E-24**): enabling technologies, emerging technologies, and enhanced human services. A connected vehicle environment (CVE) was regarded as the enabling technology to improve mobility and roadway safety in the region. The enhanced human services contain the following projects: a multimodal trip planning app (MMTPA), smart mobility hubs (SMH), mobility assistance for people with cognitive disabilities (MAPCD) app, prenatal trip assistance (PTA), and event parking management (EPM). Connected electric autonomous vehicles (CEAV) are considered emerging technologies, which were introduced to promote long-term urban transportation mobility. All these projects were managed by a central Program Management Office (PMO).

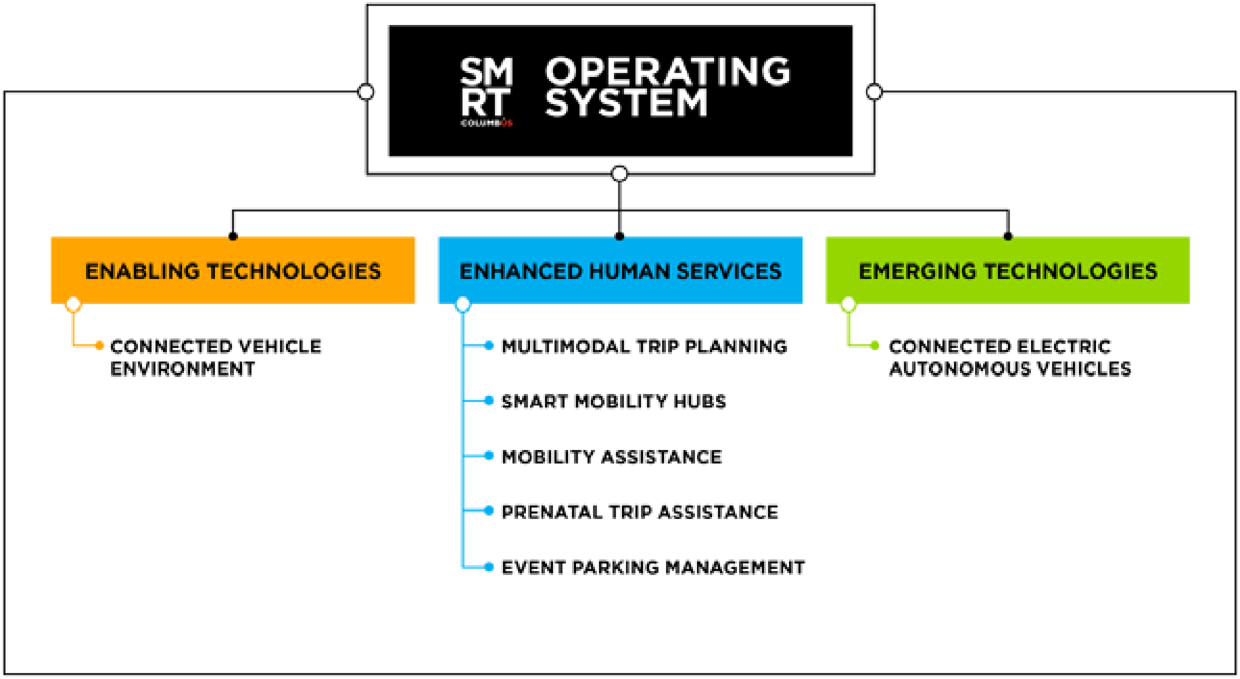


Figure E. 1: The Smart Columbus Operating System

Source: City of Columbus

The Smart Columbus Program was originally started in August 2016, and it was expected to be completed in May 2021. The specific functions of each Smart Columbs Project are introduced as follows.

The Smart Columbus Operating System (SCOS) is a dynamic and integrated data exchange platform, which collected and stored over 3,000 datasets of information, including traffic, infrastructure, weather, food services, parking, and healthy behaviors, from multiple sources such as planners, transportation organization, communities, technology provider, and app users. In addition, various visualization tools such as transportation accessibility dashboard and parking violations heat map were developed to analyze data from these datasets. The SCOS serves as the backbone for performance evaluation, research, and service improvement, given that it provides access to open data that capturing the application of advanced concepts and technologies. The SCOS was initially launched in May 2017 and has been updated in April 2018 and April 2019, respectively.

The Connected Vehicle Environment (CVE) project was implemented as a pilot program to examine the applicability of connected vehicle devices on urban mobility patterns. Through an installation of more than 1,000+ CVE devices on vehicles that commute within a few selected corridors in the City (see **Figure E-25**), the objective is to reduce traffic congestion and vehicle crashes by providing real-time information to drivers, such on emergency conditions, red-light, speed limit, school zone and so on. The onboard units have started to be installed in vehicles since December 2019, and after that in July 2020 the CVE was launched to apply these devices in reality.

Figure E. 2: The Deployed CVE Corridors, SMHs, and Self-Driving Shuttles

Source: OSU

The Multimodal Trip Planning Application (MMTPA) project focuses on the development of a MMTPA called Pivot. The Pivot is expected to improve the accessibility of residents to multiple transportation options. It also enables users to make an inquiry of information, plan, book, and pay for trips based on their preference. The Pivot, launched in beta version in 2019 and publicly in 2020, with deep-linking implemented for payment.

The Smart Mobility Hubs (SMHs) project focuses on transforming certain conventional bus stops into smart mobility hubs to enable a seamless transfer among different modes. In addition, a SMH also provides amenities, such as free Wi-Fi access and real-time transit information to facilitate trip planning. As shown in **Figure E. 2**, six SMHs were developed in the Linden and Easton areas. Linden is considered a less developed neighborhood with a relatively lower income level. Transportation has traditionally been a major issue in Linden due to the lack of public transportation and low vehicle ownership. Conversely, Easton is a more developed neighborhood and it has one of the largest malls in Mid-Ohio. Most of these SMHs provide multiple travel options, such as buses, scooters, and bike-share. SMHs started an upgrade in Fall 2019 and were opened for service in July 2020.

The Mobility Assistance (MAPCD) project was implemented to help the older and the disabled people use bus service independently in fixed routes. This application was designed with high accuracy, turn-by-turn navigator so that people with cognitive disabilities are comfortable traveling alone. In April 2019, 30 people with cognitive disabilities were selected for a test to use an application tool called Wayfinder, which helps disabled people to travel safely.

The Prenatal Trip Assistance (PTA) project focuses on improving the existing Non-emergency Medical Transportation (NEMT) system in certain designated areas by new mobility solutions. It enhances pregnant individuals' access to NEMT and connects them with health care providers. This project was implemented by a study called Rides4Baby that launched in May 2019 to examine pregnant individuals' satisfaction with transport services in eight at-risk areas where the infant mortality reduction initiative CelebrateOne is available. Moreover, it is expected to investigate whether the pregnancy outcomes and infant survival rate could be improved by using a particular transportation mode.

The Event Parking Management (EPM) focuses on developing an integrated parking system in downtown Columbus and the Short North Arts district so that travelers can search for parking information, make a reservation and finish payment in a timely manner. The project was launched in December 2020 with the development of an app called ParkColumbus and its web portal, which allows drivers to find, book, and pay for parking spaces by a one-stop shop in this app. It can reduce the vehicle circling time and reduce traffic congestion.

Lastly, the Connected Electric Autonomous Vehicles (CEAV) project was introduced to develop a testbed for the adoption of AV in designated areas so as to improve public awareness of the benefits of CEAV technology. In addition, the project aims to reduce the challenge for the first mile/last mile travel. AVs are expected to bridge the gaps between transit stations and travelers' origin and destination and therefore becomes a solution for the first mile/last mile challenge (Chong et al., 2011; Moorthy et al., 2017). In December 2018, the first self-driving shuttle named Smart Circuit was deployed to serve downtown Columbus. A free AV shuttle service connects major places of interest, such as the Center of Science and Industry (COSI) museum, the National Veterans Memorial and Museum, Bicentennial Park and the Smart Columbus Experience Center. During December 2018 and September 2019, more than 15,000 people took the shuttle and experienced the AV technology. In addition, another AV shuttle called Linden LEAP was deployed in the Linden community from July 2020 to April 2021 to provide food delivery service to lower-income families during the COVID-19 pandemic. Local residents applauded the service as it provided them with access to basic food during the challenging period.

E.1.6 Data and Method

E.1.6.1 MODELING FRAMEWORK

Figure E. 3 illustrates a modeling framework of the economic impact of smart city investment. Smart city investment generates both short-term and long-term economic effects. The economic impact analysis consists of two parts. The short-run impact analysis focuses on the evaluation of the economic impact during the project development phase (from 2017 to 2021). The impact on the macroeconomy in terms of changes in the gross metropolitan product (GMP), employment and business revenue was assumed to be achieved through the stimulus effect from the Smart Columbus Program capital investment in the corresponding economic sectors. Long-term effects refer to the economic impact generated from the operation of the systems, which is often manifested by an increase in production productivity and travel behavior changes. One should note that the long-run impacts were introduced as predictive outcomes. The results were estimated based on the corresponding survey and assumptions. Hence, it does not necessarily reflect the actual impacts of the Smart Columbus Program.

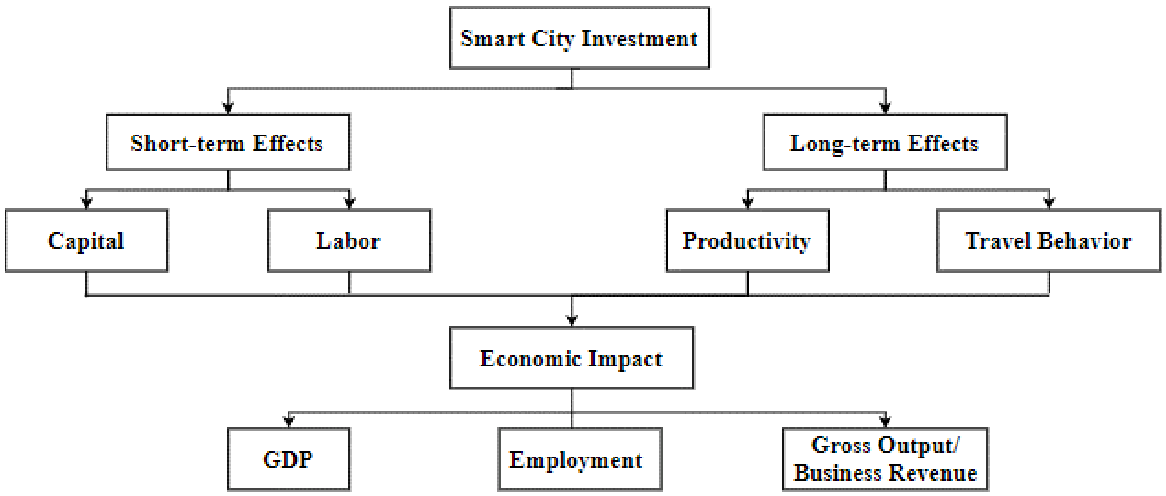


Figure E. 3: The Modeling Framework of the Economic Impact of Smart City Investment

Source: OSU

In addition, the assessment only focuses on the local economic impact on the ten counties in the Columbus Metropolitan Area.[128] Hence the model does not capture any spillover effect on other cities and regions.

Table E. 2 summarizes the total investment in Smart Columbus related projects. The data was obtained from the Smart Columbus team. During the period 2016-2020, the total fund of the project was $54.6 million, which consists of approximately $37 million from USDOT and $17.6 million from cost share partners. The final actual expenditure of the investment was $51.05 million. In terms of the comparison by sectors, 43.82% of investment was allocated to other business services-related sectors, including system engineering, project management, consulting and infrastructure system integration. The investment in information and communication sectors accounts for 34.3%, the majority of which was used to develop the SCOS. In addition, 9.13% of the investment expenditure was allocated to the local government-related sector, which was primarily related to project planning, administration and management.

Table E. 2: Factor Input Investment from the Smart Columbus Project on Different Sectors (Millions of 2018 Dollars)

Sector Project	Management	OS	CVE	MMTPA	SMH	MAPCD	PTA	EPM	CEAV	Total
Other Business Services	5.84	2.54	7.76	0.69	0.94	0.18	0.47	0.79	1.41	22.37
Information	0.27	11.87	0	2.15	0	0.03	0	0.45	0	14.78
Other Government	1.97	1.32	0.59	0.19	0.09	0.10	0.12	0.18	0.10	4.66
Construction	0	0	3.13	0	0	0	0	0	0	3.13
Communications	1.85	0.04	0.43	0	0.02	0.01	0.16	0.18	0.05	2.73
Other Transport	0	0	0	0	0.27	0	0	0	1.26	1.54

The 10 counties include Delaware County, Fairfield County, Franklin County, Hocking County, Licking County, Madison County, Morrow County, Perry County, Pickaway County, and Union County.

Sector Project	Management	OS	CVE	MMTPA	SMH	MAPCD	PTA	EPM	CEAV	Total
Education	0.55	0	0	0	0	0.28	0.46	0	0	1.29
Retail Trade	0	0	0.23	0	0	0	0.01	0	0	0.25
Insurance	0	0	0	0	0	0	0.28	0	0	0.28
Other Health & Social Services	0	0	0	0	0	0	0.03	0	0	0.03
All	10.48	15.77	12.14	3.03	1.32	0.60	1.53	1.60	2.82	51.05

Note: The summary does not include the breakdown of the removed project - Cyberphysical Systems and Truck Platooning.

Source: City of Columbus.

The impact assessment was conducted using computable general equilibrium (CGE) analysis. CGE is considered as a state-of-the-art economic impact analysis method. The model reflects multi-market interactions between individual producers and consumers to changes from external shocks, such as changes in factor inputs, productivity, technology and taxes, subject to constraints on capital, labor, and natural resources (Dixon & Rimmer, 2002). A CGE model characterizes the economy as a set of interconnected supply chains. It represents a significant advance over its predecessor, input-output (I-O) analysis, by maintaining the I-O model's strengths, such as being its simple structure and convenient calculation procedure while overcoming several limitations, such as enabling the substitution relationship of commodity, which provides a more realistic response of an economic system (Zhou & Chen, 2020). CGE models have been used extensively to assess environmental and economic impacts of transportation infrastructure investment (Chen et al., 2016; Chen et al., 2021; Chen & Haynes, 2014; Hensher et al., 2012).

The CGE model used for this assessment was developed based on the national USCGE model, which was initially developed by Rose and Oladosu (2002). The upgrade includes the development a regional social accounting matrix (SAM) that represents the economic activities of the Columbus Metropolitan Statistical Area (MSA), based on the IMPLAN data.[129] The model consists of 48 economic sectors (see **Table E-18**), with nine household groups, three government actors (two federal and one state and local), and an external agent (i.e., foreign producers). The model is static, given it does not trace the time-path of impacts, such as economic cycles associated with employment and investment changes.

The detailed discussions of the modeling structure could be viewed in Prager (2013). The model has a few classical structures as the standard CGE model framework. For instance, international trade is represented through an Armington substitution function between imports and domestic production. The substitution between exports and domestic sales is represented through a constant elasticity of transformation function. Household consumption is represented by a linear expenditure system of aggregate commodities. The input and import substitution elasticity parameters were sourced and checked against the literature. The production activities are structured in the form of a constant elasticity of substitution (CES), in which factor inputs, such as capital and labor, are substitutable, subject to the input share parameter and the CES. The production function is hierarchical, representing sequential decision-making relating to the choice of input combinations in each tier or "nest."

Table E-84 summarizes the key mechanisms of CGE simulations for the short-run and the long-run effects. To measure the economic impact of the investment on different Smart Columbus projects, ten scenarios were developed, which correspond to the program-level management, the eight individual projects, and one scenario of the overall impact. The CGE drivers for the short-run economic impact include factor inputs for labor and capital, which were calculated using the aggregate investment of the associated sectors (see **Table E. 2**) divided by the level of factor inputs in the base case.

Table E. 3: The Mechanism of CGE Simulations

Content	Short-run effect	Long-run effect
CGE driver	Factor input shock of affected sectors, according to the input data listed in **Table E-14**	Productivity shock of transportation-related sectors 13.51% increase in transit productivity (based on the Smart Columbus travel survey)[130] Household expenditure shock of travel-related services 9.27% increase in urban travel-related service (based on the Smart Columbus survey)
Closure rule	Keynesian rule (wage is fixed, while labor demand is endogenized)	Neoclassical rule (labor demand is exogenized while wage is endogenized)
Data source	City of Columbus, financial expenditure data	Smart Columbus travel mailer survey (December 2019; November 2020)
Assumption	It is assumed that the capital expenditure was only allocated to the local service providers and contractors. The analysis measures the impact of the aggregate investment in a lump sum. Hence, the effect of yearly adjustment, such as capital accumulation or depreciation, was not considered.	The level of productivity shock was determined by the percent of travel time savings due to the reduction of traffic congestion. The level of household expenditure shock was determined by the percent change of trip purposes. The effect of COVID-19 was not simulated explicitly. It is assumed the long-run effect could be achieved if the travel behavior change is applied to all the residents in the City.

Source: OSU

The long-run effects are measured through the shocks of a productivity increase of urban transportation related sectors (such as transit service) and household expenditure on travel related services. The specific magnitude of shocks was based on the travel survey conducted by the Smart Columbus Program project evaluation team. The changes in travel behavior and expenditure captured in the survey were assumed and applied to the entire local economic system. In addition, given that the surveys of the Smart Columbus projects were primarily conducted before and during the outbreak of the COVID-19, one should note that the responses from the travel survey could primarily reflect the influence of COVID-19 instead of from the Smart Columbus projects. Hence, the results of the long-run effect should be read with caution as it was mainly introduced for a demonstrative purpose.

The model simulates macroeconomic impacts in terms of changes in gross output (business revenue), GMP and payroll as a response to the various shocks. For instance, in the short-run impact analysis, an increase in factor inputs would lead to a higher volume of production, which hence, increases gross output (business revenue) and GMP throughout the supply chain. In the long-run case, the increase in productivity and household expenditure is likely to stimulate the boost the supply of intermediate and final goods and services, which in turn, may promote the expansion of economic outputs.

E.1.7 Results

Table E. 4 summarizes the economic impacts of the various Smart Columbus projects. In terms of the short-run effect, the total capital investment implemented during the project development stage is likely to generate a GMP growth by $147.87 million or a 0.078% increase from that at the base year level. $51.05 million of the impact was generated from a direct effect from the investment expenditure. $96.82 million was found to be generated from the indirect effects, which includes both the effects stemming from business expenditure through the supply chain and household spending induced by the increased supply and income. In addition, the short-run effects of the Smart Columbus investment are likely to generate a job increase by 4,220 or an employment increase by 0.241% as compared with the level in 2018. 719 jobs were generated through a direct effect from the expenditure from the Smart Columbus Program- and project-related staff members, consultants, and subcontractors, whereas the remaining job increase is attributable to the indirect effect on the affected sectors through the supply chain.

The expenditure in program-level management has generated an increase of GMP by $32.44 million, two thirds of which was due to the indirect impacts on the local economy. Similarly, it also generates 924 jobs increase, 80% of which was achieved through the indirect impact. In terms of the impact by specific projects, the simulation analysis reveals that the investment expenditure in developing the SCOS is likely to generate an increase in GMP and employment by $42.82 million and 869, respectively, which has the largest economic impacts among the eight sub-projects. The impacts of the investment in CVE rank the second, which contributes to a GMP increase by $35.66 million and an average job increase of 1,003.

In addition, the assessment also evaluated the long-run economic impact of the Smart Columbus projects. Assuming the reduction of the urban traffic congestion and the increase of urban transit services captured in the Smart Columbus Program projection evaluation would eventually lead to a corresponding ratio of changes in productivity and household expenditure on urban transit services, successful deployment of the Smart Columbus projects and utilization of the services is likely to generate a $671.28 million or 0.538% increase in GMP, and 7,039 jobs or an employment increase of 0.3%. 92% of the effect on GMP and 74% of the effect on employment should be attributed to the productivity improvement in urban transit-related sectors.

In terms of the impact by economic sectors, **Table E. 5** summarizes the impact of the top ten economic sectors that were influenced by the Smart Columbus Program investments. The results show that in the short run, the Smart Columbus Program investments had a substantial impact on business services related sectors, such as engineering consulting and project management as well as information, medical service and transportation related sectors. In addition, wholesale and retail, trucking, and aviation were also found to have relatively significant impacts from the Smart Columbus Program investment in the long-run. Such a result suggests that the Smart Columbus Program may generate a relatively larger impact on the local economy if the travel behavioral change (e.g., due to the reduction of congestion, and increase in transit satisfaction) captured in the survey could be materialized and translated into changes in productivity and household expenditure in the long-run.

Overall, the multiplier of the Smart Columbus Program and project investments was found to range between 1.71 and 2.09, with an overall average rate of 1.9. The result suggests that each dollar invested in the Program is associated with a 1.71 – 2.09 dollar increase in value-added to the local economy.

Table E. 4: Economic Impact of the Smart Columbus Investments

Project	Impact Type	Number of Jobs				Value Added GMP ($ millions)				Multiplier
		Direct	Indirect	Total	% Change	Direct	Indirect	Total	% Change	
Management	Short-Run	190	734	924	0.064%	10.48	21.96	32.44	0.018%	2.09
SCOS	Short-Run	178	691	869	0.060%	15.77	27.05	42.82	0.022%	1.71
CVE	Short-Run	171	832	1,003	0.057%	12.14	23.52	35.66	0.019%	1.94
MMTPA	Short-Run	36	174	210	0.012%	3.03	5.25	8.28	0.004%	1.73
SMH	Short-Run	20	95	115	0.007%	1.32	2.64	3.96	0.002%	2.00
MAPCD	Short-Run	11	51	62	0.004%	0.60	1.24	1.84	0.001%	2.06
PTA	Short-Run	22	108	130	0.007%	1.53	2.96	4.49	0.002%	1.94
EPM	Short-Run	25	122	147	0.008%	1.60	3.12	4.72	0.003%	1.95
CEAV	Short-Run	35	171	206	0.012%	2.82	5.44	8.26	0.004%	1.93
Total	Short-Run	719	3,501	4,220	0.241%	51.05	96.82	147.87	0.078%	1.90
Total_P	Long-Run	-	5,207	5,207	0.222%	-	622.46	622.46	0.499%	-
Total_E	Long-Run	-	1,821	1,821	0.078%	-	48.43	48.43	0.039%	-
Total	Long-Run	-	7,039	7,039	0.300%	-	671.28	671.28	0.538%	-

Notes:

a) The number of jobs was calculated using the aggregate payroll divided by the mean wage level ($54,784.2) of the Columbus in 2018.

b) The multiplier, also known as the Keynesian multiplier, reflects the ratio between the indirect value-added and the direct value-added from the capital expenditure of the projects. Hence, it is only applicable in the short-run impact scenario.

c) Total_P and Total_E refer to the program-level impacts achieved through an increase in productivity of urban transit services and an increase of household expenditure in urban transit-related services. The total long-run effect includes both of the aforementioned long-run effects.

d) All the values were measured in 2018 constant dollar terms.

Source: OSU

Table E. 5: Impacts of the Top 10 Sectors Influenced by the Smart Columbus Projects

Rank	Economic Sector	Level Change			% Change		
		Output	GMP	Payroll	Output	GMP	Payroll
Short-Run Impact							
1	Other Business Services	42.72	30.39	26.80	0.15%	0.15%	0.17%
2	Information	16.00	10.14	2.82	0.37%	0.40%	0.25%
3	Medical Services	9.65	6.64	6.52	0.07%	0.07%	0.09%
4	Other Transport	9.16	5.80	4.51	0.18%	0.19%	0.20%
5	Wholesale Trade	8.23	4.82	4.13	0.07%	0.06%	0.12%
6	Retail Trade	5.87	4.08	2.75	0.06%	0.06%	0.09%
7	Other Health & Social Services	5.25	3.90	3.60	0.08%	0.08%	0.11%
8	Manufacturing	6.03	3.72	3.58	0.05%	0.05%	0.09%
9	Hotel and Restaurants	5.09	3.40	3.01	0.08%	0.08%	0.12%
10	Real Estate	3.79	0.76	0.44	0.02%	0.01%	0.06%
Long-Run Impact							
1	Other Transport	189.677	103.756	100.854	3.40%	3.00%	3.90%
2	Wholesale Trade	105.369	36.602	27.848	0.80%	0.45%	0.68%
3	Retail Trade	71.961	32.352	19.020	0.72%	0.46%	0.56%
4	Other Business Services	39.219	24.524	23.866	0.12%	0.10%	0.13%
5	Truck Transport	53.413	22.055	21.067	1.89%	1.42%	2.02%
6	Air Transport	28.067	18.325	14.396	1.45%	1.21%	1.48%
7	Other Health & Social Services	16.501	11.594	10.745	0.23%	0.22%	0.29%
8	Medical Services	17.295	10.939	10.733	0.11%	0.11%	0.13%
9	Education	7.263	5.242	5.076	0.46%	0.46%	0.51%
10	Personal Services	6.830	4.571	4.351	0.26%	0.25%	0.48%

Notes:

a) Ranking was based on the level of GMP both in the short-run and the long-run, respectively.

b) All numbers were measured in millions of dollars.

c) The change does not consider the effect of price adjustment.

Source: OSU

E.1.8 Conclusions

This study evaluated the economic impact of smart city investment using the Smart Columbus Program as an example. To capture the influence of the infrastructure investment on various specific smart city projects, both the short-run and long-run impacts on the local economy were evaluated. Overall, the research reveals that the investment in smart city infrastructure projects could generate a short-run impact through stimulating the growth of the economy, with primarily positive effects on business and IoT-related sectors, such as information, and communication, at the implementation stage. Conversely, the long-run impact can be achieved through an increase in productivity of urban transportation-related sectors and an increase in the demand for mobility services.

However, it should be noted that whether these long-run impacts of smart city investment could be achieved or not depends on several critical conditions. First, it is fundamental to have public support from the very beginning of planning so that the infrastructure projects can be delivered on schedule. In addition, it is also essential to increase public awareness of the smart city development so that the systems can be widely adopted by the residents upon completion to generate a large-scale impact on the economy.

Second, the levels of impacts are also subject to the types of adopted technologies and the scale of deployment. For instance, as observed from other cases of smart city development, a variety of IoTs was either introduced or applied at various scales. One should be aware that successful implementation of a smart city initiative requires not only effective coordination and cooperation among different stakeholders, especially during the initial planning and project implementation stage, but also a sustainable approach in technology development, investment and applications.

One should also note that the study has several limitations, which could be further refined or expanded in future research endeavors. For instance, the assessment was conducted using a static CGE framework, in which neither the dynamic effects of capital accumulation and depreciation government nor any spatial spillover effects on other regions from the Smart Columbus Program investments were captured. In addition, the assessment did not capture any uncertainties that may potentially impact the economy, such as the negative shocks from the COVID-19, although the outbreak occurred amid the Smart Columbus Program deployment. Future studies could be improved by adopting a more advanced framework, such as the dynamic multi-regional CGE model. Nevertheless, the study provides a useful analytical framework for the economic impact assessment of smart city investment. It also provides insights for city planners to better understand the economic benefits of smart city initiatives, which may facilitate rational future investment decision-making both in Columbus and other cities.

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Table E. 6: List of the Economic Sectors

ID	Sector
1	AOTH Other Agriculture
2	ABEEF Beef Cattle Ranching and Farming
3	ADARY Dairy Cattle Ranching and Farming
4	APOUL Poultry and Egg Production
5	AOLVS Other Livestock
6	CRUD Crude Oil and Natural Gas
7	COAL Coal
8	OMIN Other Mining
9	PELE Private Electric Utilities
10	GASU Gas Utilities
11	SANT Sanitary Services
12	CNSR Construction
13	MOFD Other Food Processing

ID	Sector
14	MFML Fluid Milk Manufacturing
15	MOML Non-Milk Dairy Product Manufacturing
16	MANM Animal Slaughtering and Meat Processing
17	MFSH Seafood Product Preparation and Packaging
18	MOAF Other manufacturing
19	MPET Petroleum Refining
20	MCAR vehicle manufacturing
21	WTRD Wholesale Trade
22	VSAE whole retail motor vehicle and parts dealers
23	RTRD Retail Trade
24	TAIR Air Transport
25	TRUK Truck Transport
26	TWAT Water Transport
27	TRAL Rail Transport
28	TOTH Other Transport
29	TLTP Private Transit
30	INFO Information
31	COMC Communications
32	SECB Security Brokers
33	BANK Finance Banking & Credit
34	INSR Insurance
35	REST Real Estate
36	AERL automotive equipment rental and leasing
37	PSRV Personal Services
38	OBSV Other Business Services
39	VSRV Veterinary Services
40	WAST Waste Manage Remediation
41	EDUC Education
42	MEDC Medical Services
43	ENTR Entertainment
44	HOTR Hotel and Restaurants
45	VMRS automotive repair and maintenance
46	OSOC Other Health & Social Services
47	OGOV Other Government

ID	Sector
48	NCMP Noncomparable Imports

Source: OSU

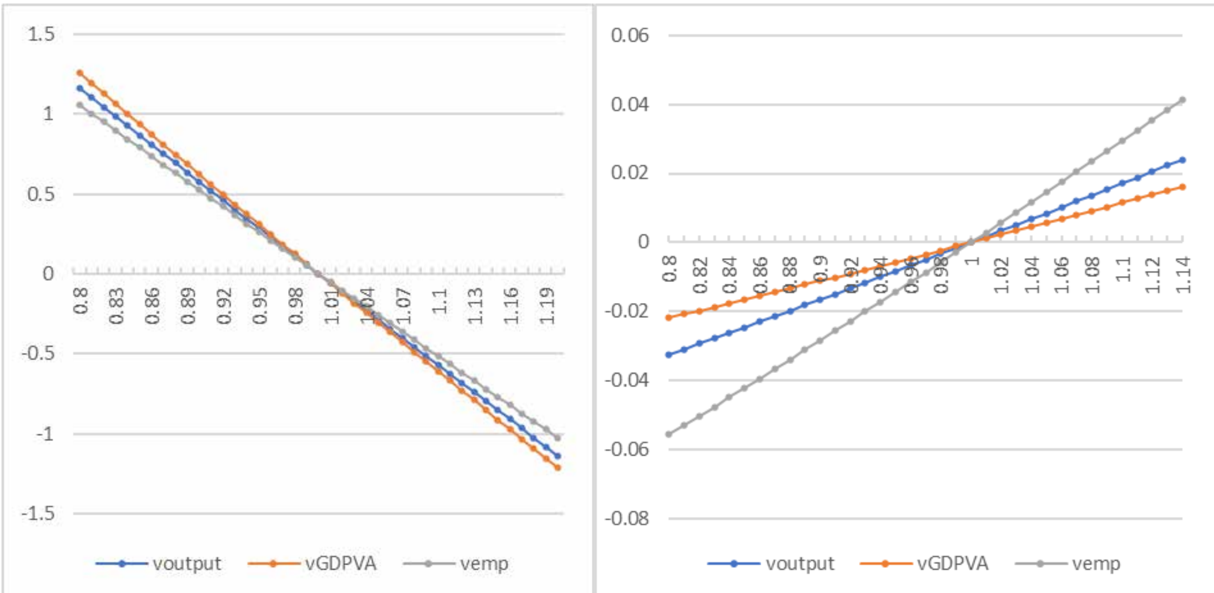

Figure E. 4: Sensitivity Analysis of the Long-Run Impacts

Source: OSU

E.2 ACCESSIBILITY ANALYSIS

E.2.1 Introduction

Accessibility refers to the ability to reach resources, activities and opportunities in a community, including the locations of key travel origins such as home and work, the geographic distribution of resources, and the ability of the transportation systems to facilitate movement among these locations. The theory of accessibility measurement dates back to the mid-20th century; it is now well-developed with a coherent set of quantitative measures (Handy, 2020; Levinson and Wu, 2020; Wu and Levinson, 2020). The intent of Smart Columbus to improve ladders of opportunity within the community dovetails precisely with this perspective on transportation system performance and its value to a community.

In this analysis, a *space-time accessibility* approach is used that focuses on the spatial extent of reachability given a designated travel origin and *time budget* for travel, taking into account the performance of the transportation system (Miller 2017). This can include: i) the vehicle movement speeds afforded by the street network and its attributes; ii) public transit routes and schedules; ii) the sidewalk network for walking and public transit access; iii) the location and availability of docked bikeshare stations at the time of travel; iv) the locations of dockless micromobility vehicles at the time of travel.

The space-time accessibility approach generates a spatial region that represents the geographic extent of accessibility given the travel origin and time budget. Using Geographic Information Systems (GIS) software, this region can be overlayed with georeferenced business, institution, resource and other activity locations. The results are maps of spatial accessibility and the subset of the activity locations that are accessible. It is important to note that this does not represent actual travel to these locations; rather, it highlights the physical limits on potential mobility afforded by the transportation system in that environment.

The focus and attention is on the Pivot. The hypothesis is that Pivot can generate expanded accessibility by facilitating multimodal trip planning. Multimodal trips can provide better space-time accessibility than single-mode trips by extending the capabilities of any single mode, for example, bikeshare or micromobility mitigating the first mile/last mile problem in public transit. However, while single mode trip planning is relatively easy, multimodal trip planning is more difficult: this is the gap filled by the Pivot.

The geographic extent of space-time accessibility via single-mode travel (representing the pre-Smart Columbus/Pivot situation) are compared with the space-time accessibility of multimodal trips that can be discovered via the Pivot. These regions are also overlayed with georeferenced employer and health care provider data and compare the differential access to these key community resources. **Section E.2.2** describe the research design, data sources, space-time accessibility computations and overlay methods.

E.2.2 Data and Methods

E.2.2.1 RESEARCH DESIGN

The research design is as follows:

1. Designate a travel origin and travel time budget
15. Compute the space-time accessibility region corresponding to walk and bus – this represents single mode trip planning that was readily available prior to Smart Columbus
16. Compute the corresponding space-time accessibility regions corresponding to multimodal trips afforded by the Pivot
17. Overlay these regions with georeferenced business and health care provider data
18. Compare the accessibility regions using mapping (spatial extent) and graphics (business and health care provider access)

The process is depicted in Figure E. 5.

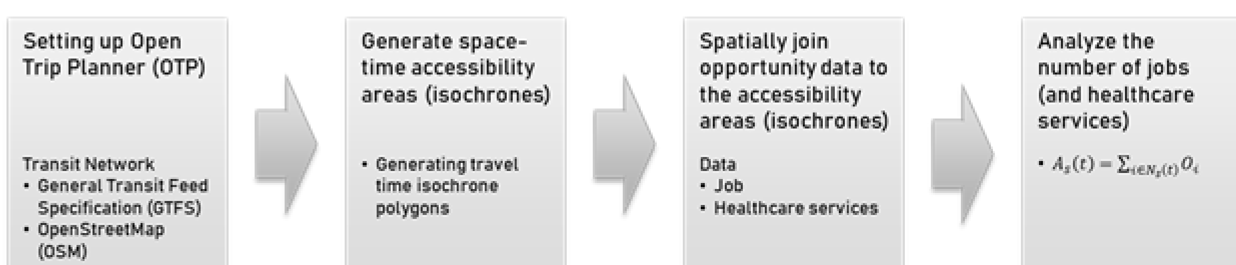

Figure E. 5: Analysis Steps for Accessibility Impacts Assessment

Source: OSU

E.2.2.2 SELECT EMPLOYERS OF INTEREST

The locations of jobs in the study area were obtained from an extract of the Longitudinal Employer-Household Dynamics (LEHD) survey[131] conducted by the U.S. Census Bureau. The dataset includes listings for places of employment including the geographic coordinates of the location and the number of jobs at the location. Jobs are further broken down into high-skill jobs and low-skill jobs. Low-skill jobs are those available to workers whose education level is completion of high school (or equivalent) or below high school. High-skill jobs are those available to workers whose education level is some college, associate's degree, bachelor's degree, or an advanced degree. Using GIS software, the selected places of employment based on their coordinates are georeferenced, allowing them to by spatially overlaid with the accessibility region. The locations for all places of employment are depicted in **Figure E. 6**.

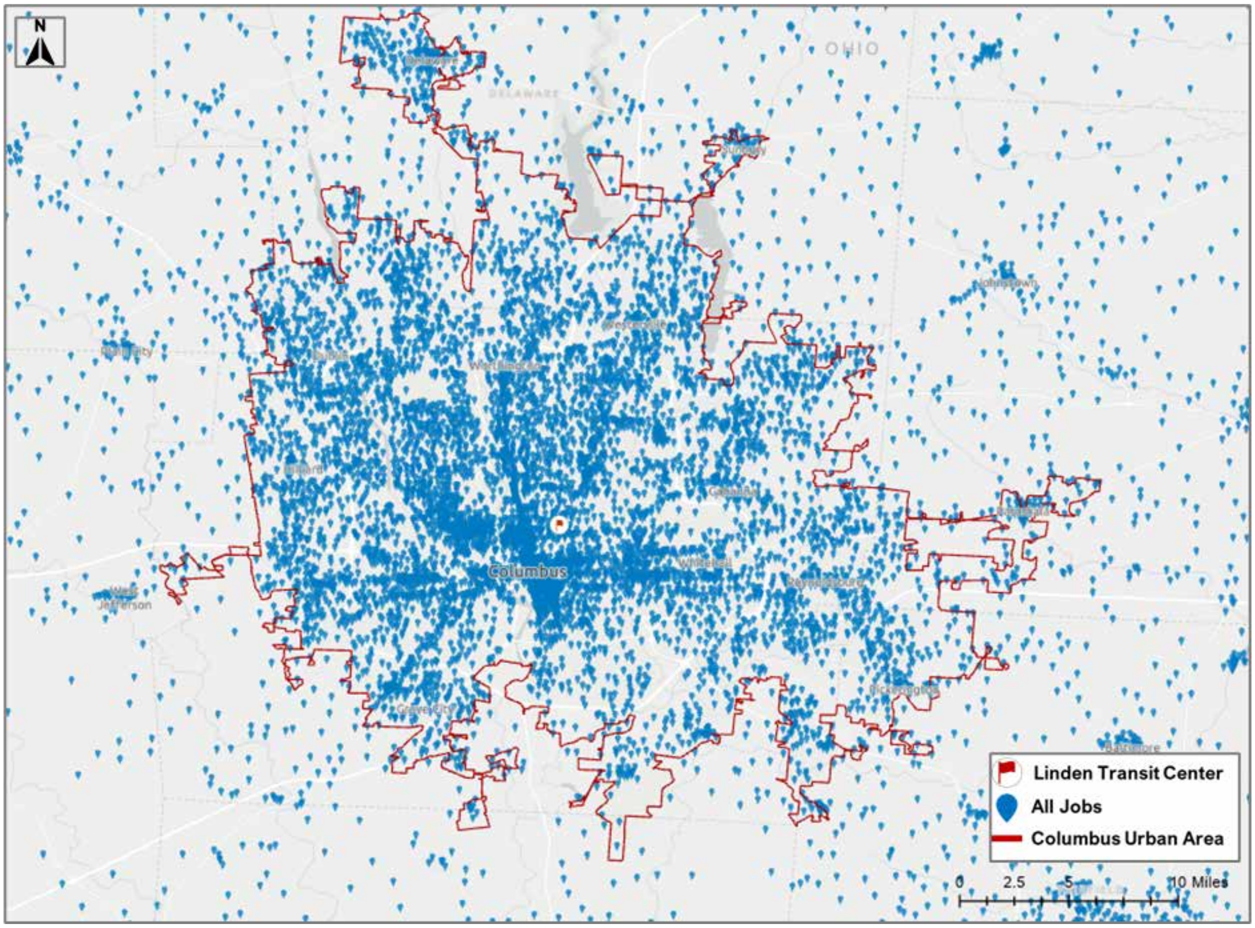

Figure E. 6: All Job Locations

Source: OSU

[131] https://lehd.ces.census.gov/data/

E.2.2.3 SELECT HEALTH CARE PROVIDERS OF INTEREST

The locations of health care providers of interest in the study area were obtained from an extract of InfoGroup[132] business listings. The businesses in the database are classified according to the North American Industry Classification System (NAICS). Geographic coordinates are provided for each business. Businesses identified by NAICS code 62, which includes health care and social assistance businesses are selected for analysts. Additionally, the subset of these business identified by code 62111 are extracted, which includes offices of physicians. Using GIS software, the selected businesses based on their coordinates are georeferenced, allowing them to by spatially overlaid with the accessibility region. The locations for all health care businesses are depicted in **Figure E. 7**. Locations of offices of physicians are shown in **Figure E. 8**.

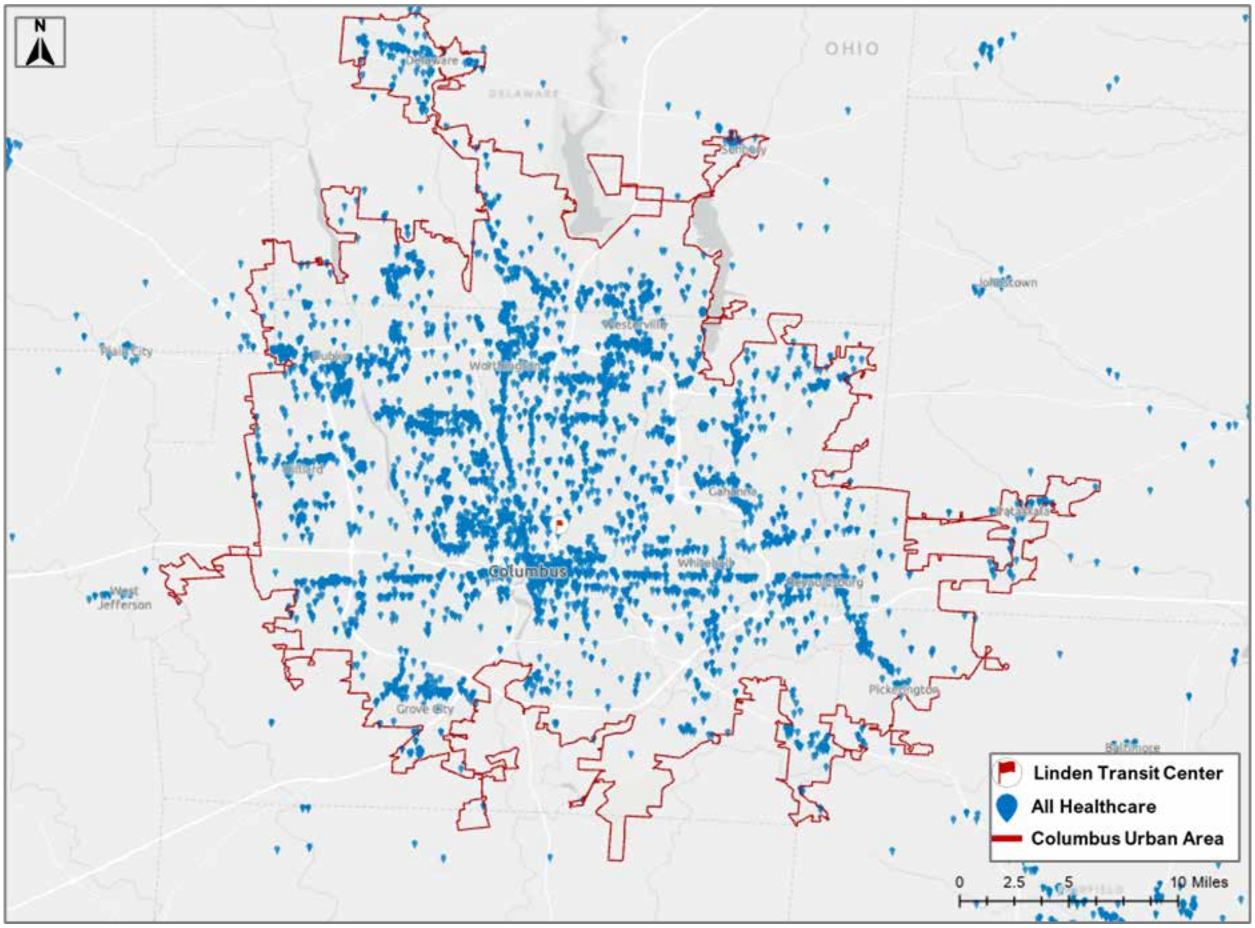

Figure E. 7: All Health Care Locations

Source: OSU

[132] *InfoGroup is now known as Data Axle: https://www.data-axle.com/*

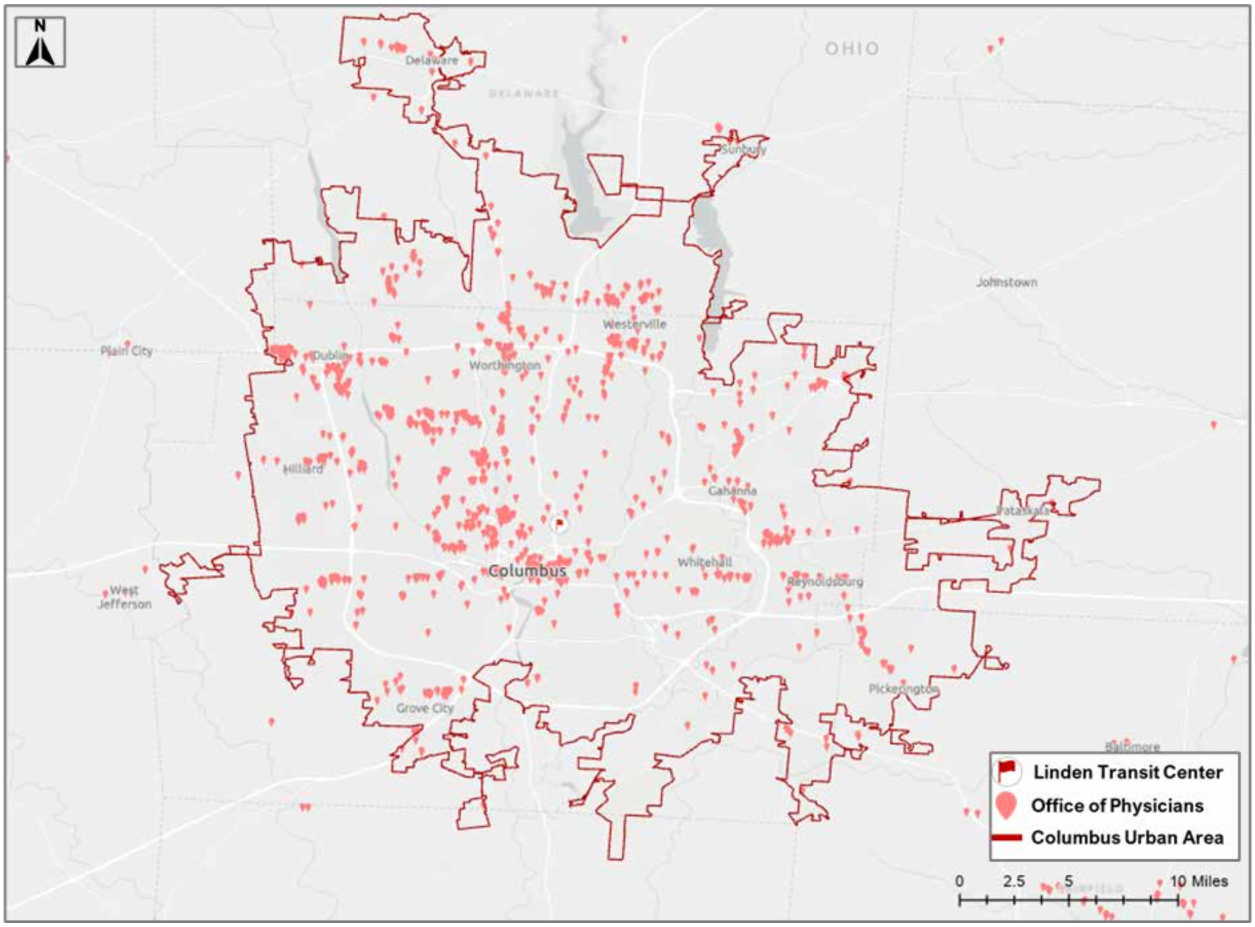

Figure E. 8: Physicians' Office Locations

Source: OSU

E.2.2.4 DETERMINE TRAVEL ORIGIN AND TIME BUDGET

A location in Linden neighborhood is chosen, specifically the Linden Transit Center, to represent the neighborhood as a travel origin and 30 minutes as a representative time budget for travel. 30 minutes represents the average one-way commute time in many societies, including the U.S. (sometimes referred to as *Marchetti's travel time constant*; see Schafer and Victor 2020).

E.2.2.5 COMPUTE SPATIAL ACCESSIBILITY REGION

The spatial accessibility region is solved as follows for the selected neighborhood. Given a travel origin and a time budget, all possible paths through the multimodal transportation network starting at the travel location, extending outward until the time budget is exhausted is computed. For ease of visual interpretation and integration with business location data, the computed accessible subnetwork is generalized using planar space region bounded by travel time isochrone.

The accessibility regions were computed using a tool called OpenTripPlanner[133] (OTP). OTP is an open-source web application that provides routing and analysis services for multimodal networks. An instance of

[133] http://www.opentripplanner.org/

OTP provides the routing services used by the Pivot, and a replica is used of this instance to compute the spatial accessibility region. The replica was provided by Etch (the firm that created Pivot) on April 23, 2021. This OTP instance uses Open Street Map (OSM) data for routing on streets and bicycle/pedestrian pathways and supports multi-agency public transport routing through imported General Transit Feed Specification (GTFS) feeds.

Prior to the introduction of Pivot, planning a trip that included multiple modes was a largely manual process and was impractical due to the complexity of managing multiple independent planning tools. The model accessibility is divided into two scenarios:

1. Pre-treatment: The first scenario represents the trip planning environment prior to the Smart Columbus Program and includes only two modes, namely walking and bus.
2. Post-treatment: The second scenario represents the trip planning environment after the introduction of SmartColumbus projects and includes all available modes, namely walking, bus, bicycle, rented bicycle (CoGo), and rented scooter (Lime, Byrd).

The accessibility regions for each of these scenarios were computed by selectively excluding modes of travel from the travel time isochrone computation using the analysis features of OpenTripPlanner. Since the accessibility calculations are based on the detailed bus schedules, Wednesday, February 3, 2021, is chosen as a representative day. Three representative trip origin times were designated: 9 am (representing morning peak travel time), 1 pm (representing off-peak travel time), and 6 pm (representing evening peak travel time).

The modeled pre- and post-treatment accessibility areas for each of the time periods are shown in **Figure E. 9** through **Figure E. 12**. **Figure E. 9** shows a zoomed-out view of the 9 am accessibility areas that shows the study area in its larger geographic context in the Columbus urban area. In these figures, the purple region represents the pre-treatment accessibility area and the green region represents the post-treatment area. Compared to the pre-treatment area, the post-treatment area covers a greater geographic extent. Some of the expanded coverage is contiguous and compact, especially in the portion of the study area closest to the central business district in the south and west. This is consistent with the greater on-street mobility afforded by access to micromobility options. Other expansion occurs as spurs and islands, especially in the far north, east, and west reaches. This is likely due to faster access to transit stops, which allows travelers to apply more of their travel time budget to reach more distant stops on the bus network or to make connections to other lines that they could not reach previously. The general patterns of the pre/post accessibility areas are similar at all times of day, however there are minor variations due to frequency of the bus service and exact arrival time of buses at particular stops. Accessibility is somewhat greater for peak hours (9 am, 6 pm) compared to off peak (1 pm), most likely due to the higher frequency of bus service at these times. Note that this analysis does not account for the impacts of traffic and bus delays, which would tend to have an adverse effect on accessibility.

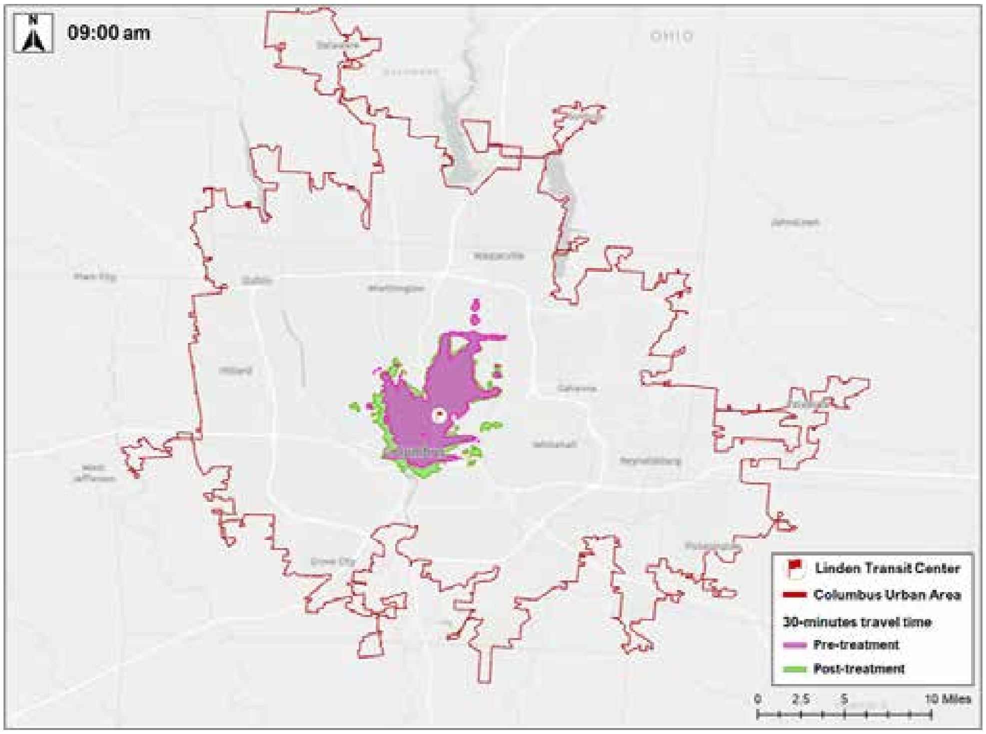

Figure E. 9: Pre/Post Accessibility Change (9 am), with Regional Context

Source: OSU

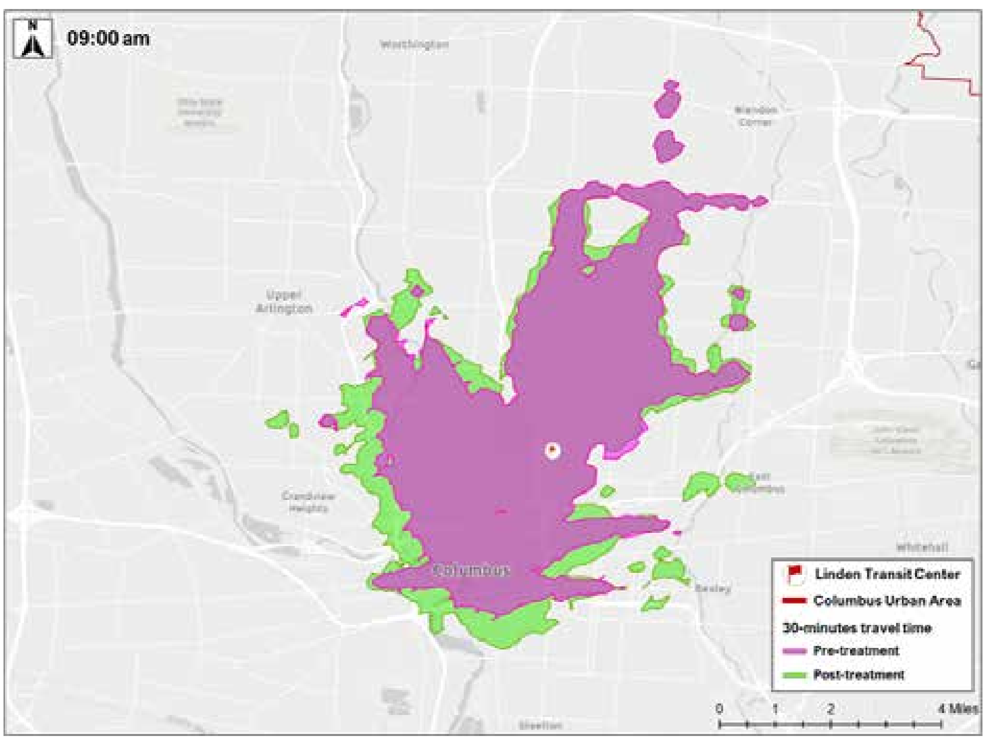

Figure E. 10: Pre/Post Accessibility Change (9 am)

Source: OSU

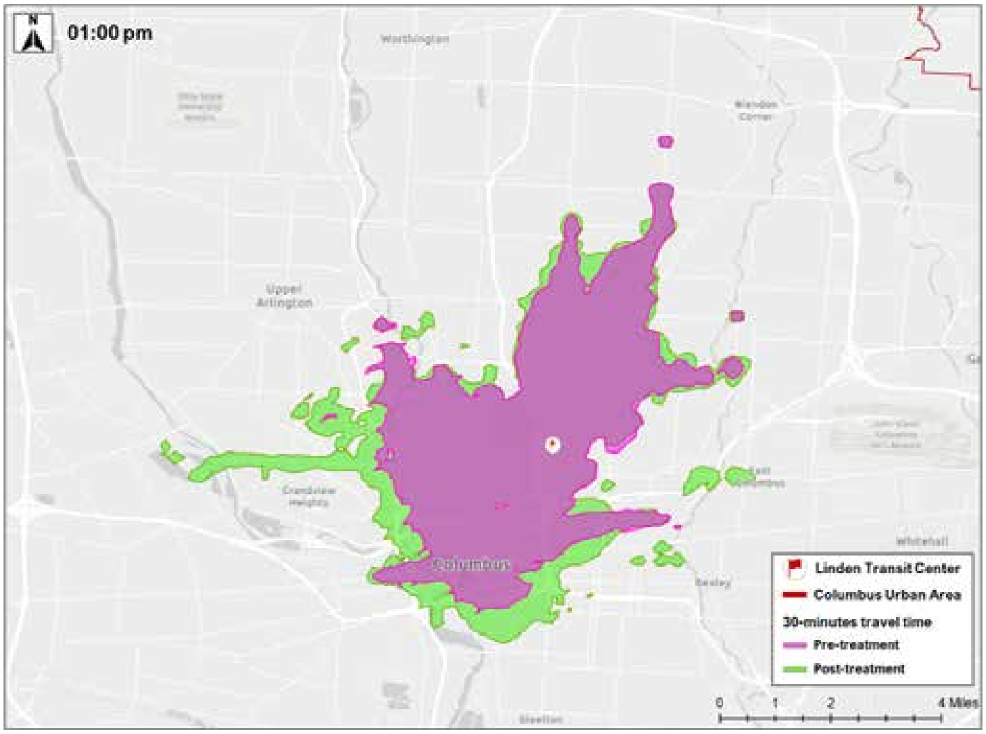

Figure E. 11: Pre/Post Accessibility Change (1 pm)

Source: OSU

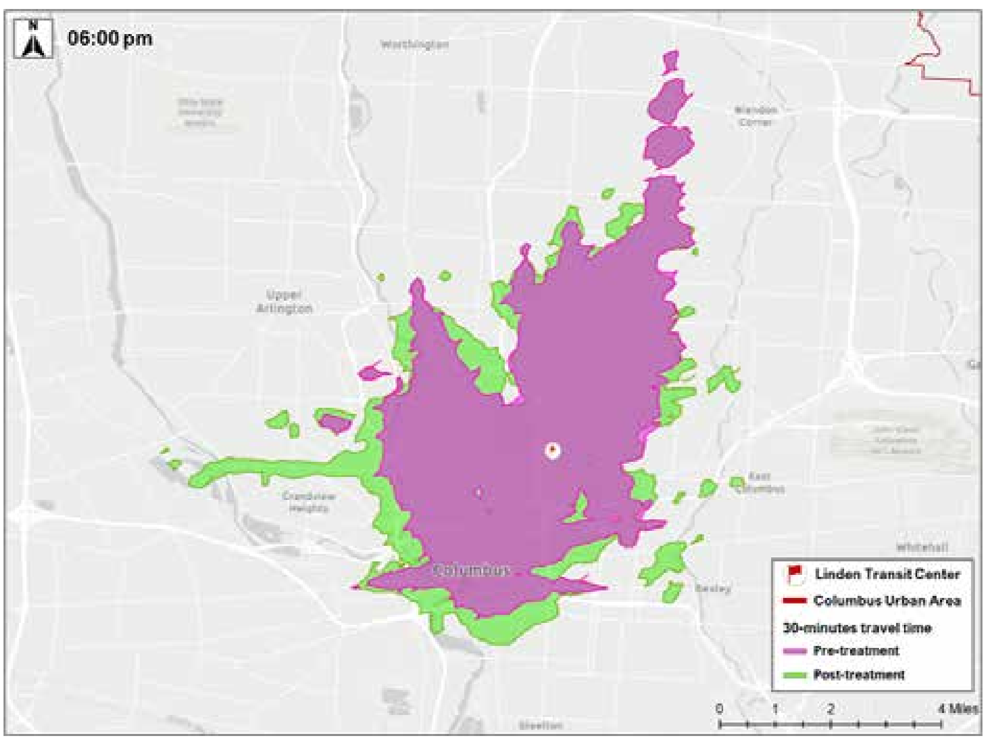

Figure E. 12: Pre/Post Accessibility Change (6 p.m)

Source: OSU

E.2.2.6 ESTIMATE ACCESSIBLE EMPLOYERS AND HEALTH CARE PROVIDERS

The last step is to compute the accessibility of employers and health care providers (collectively referred to as *opportunities*) for each combination of scenario and time of day. The accessibility is defined as follows:

where is the number of jobs (or health care services) within the accessibility area, is the origin of travel (in this case Linden Transit Center), and is the time budget (t=30 minutes). With regard to jobs, represents the number of opportunities provided by the employer at location . In the case of heath care services, represents a single business and thus has as value of 1 for all locations. To determine which opportunities should be included in the sum and GIS software is used to perform a point-in-polygon analysis for each opportunity to determine whether it does or does not fall in each accessibility area polygon.

E.2.3 Results

As noted above, the access to multiple modes of transportation provided by the multimodal trip planning capabilities of the Pivot resulted in expansion of the accessibility areas for all time periods relative to the single-mode trip-planning options that existed previously. The expansion of the accessibility areas was accompanied by access to a greater number of jobs. This is evident from **Figure E. 13** to Figure E. 14, which show the total number of jobs accessible post-treatment (all modes) compared with those accessible pre-treatment. These graphs show a modest increase in access to both high-skill and low-skill jobs for all time periods.

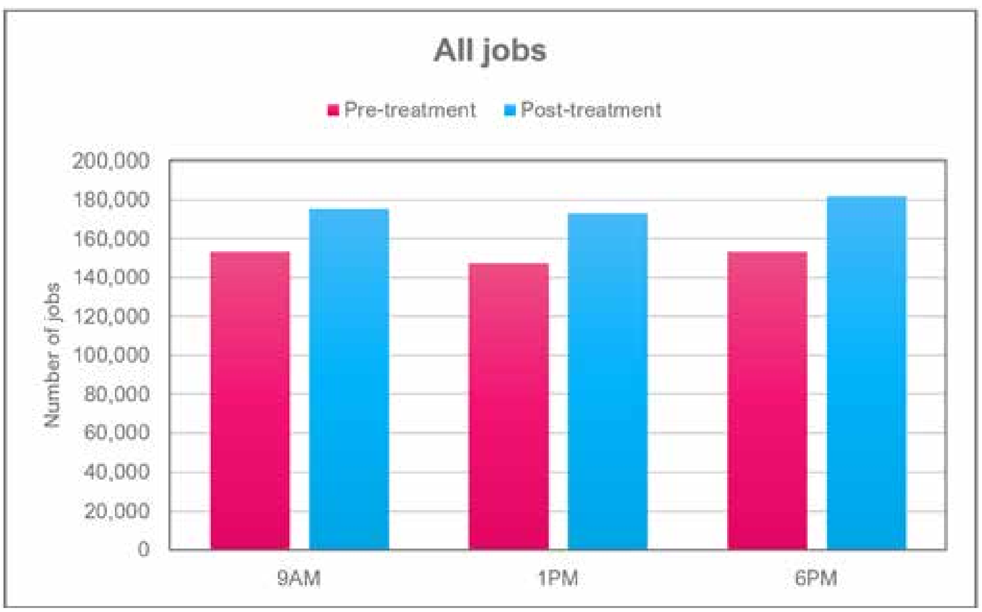

Figure E. 13: All Jobs Accessible Within 30 Minutes

Source: OSU

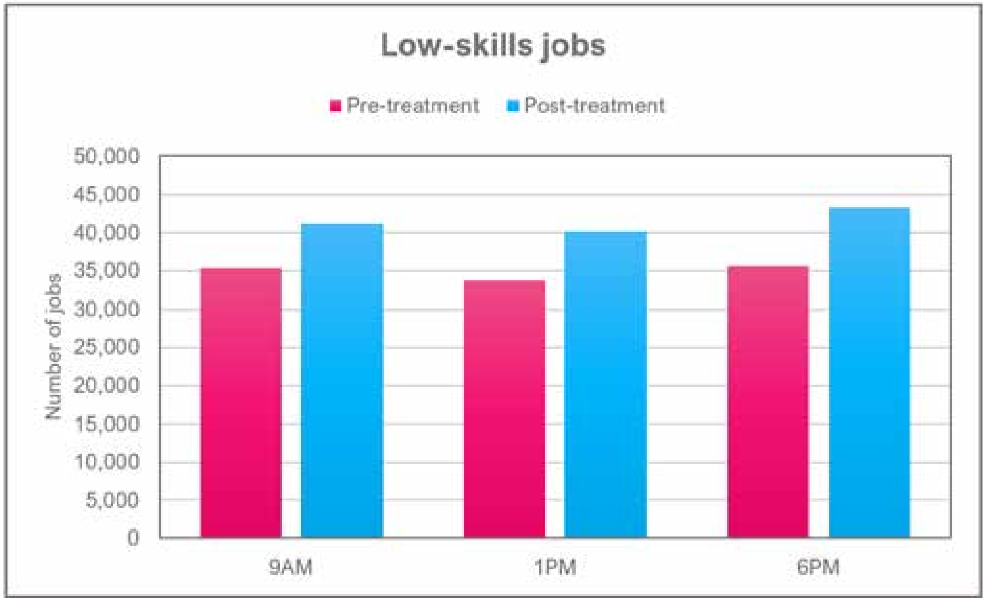

Figure E. 13: Low-Skill Jobs Accessible Within 30 Minutes

Source: OSU

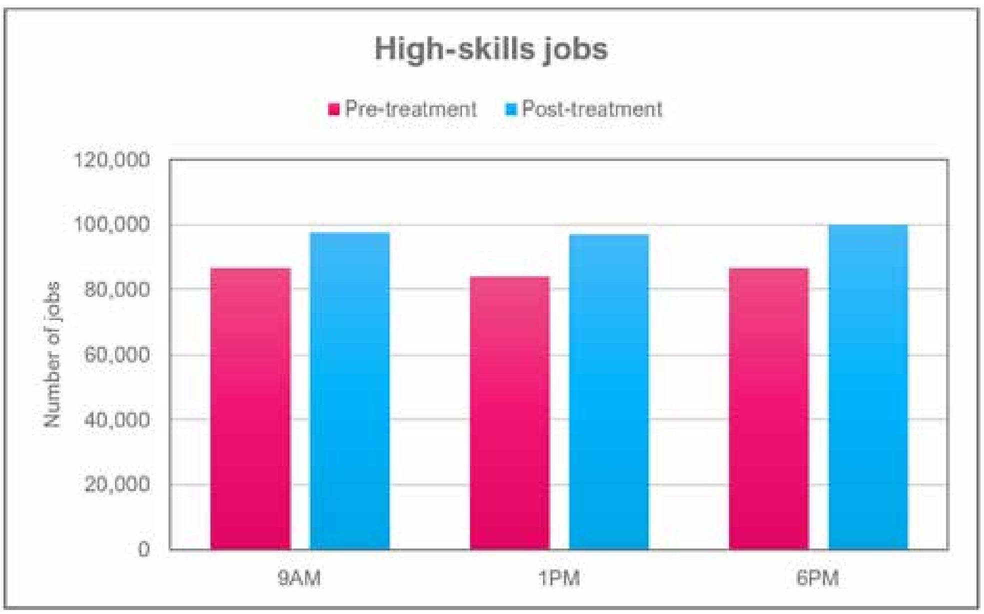

Figure E. 14: High-Skill Jobs Accessible Within 30 Minutes

Source: OSU

The degree of the change in accessibility is more apparent when expressed as net change, as shown in **Figure E. 15** and **Figure E. 16**. The increase in accessible jobs ranged from approximately 12.6% to 21.6% depending on time period and skill class. The 6 pm time period experienced the greatest gains overall with a gain of 28,244 jobs in any class (18.4%). The 9 am time period experienced the least gains at 22,095 jobs in any class (14.4% increase). Although the absolute change for high-skill jobs was greater, low-skill jobs experienced a greater proportional change due to lower total number of low-skill jobs in the area.

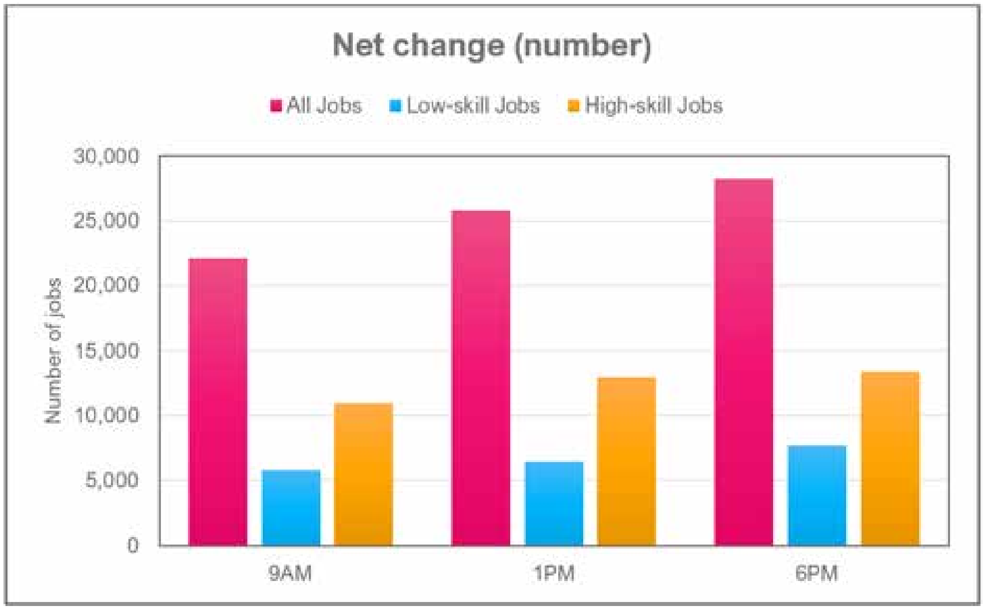

Figure E. 15: Net Absolute Change in Jobs Accessible Within 30 Minutes

Source: OSU

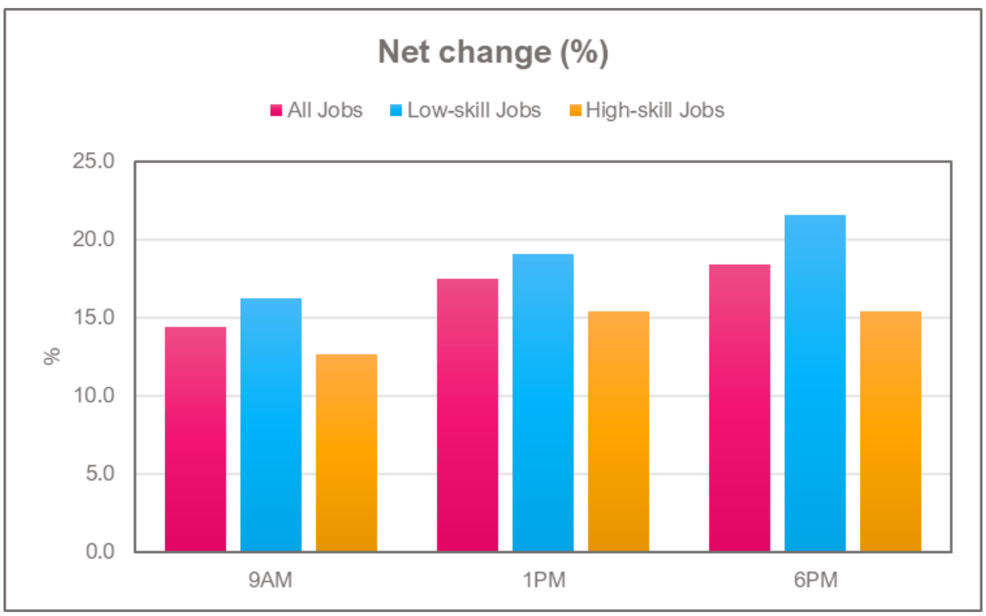

Figure E. 16: Net Percent Change in Jobs Accessible Within 30 Minutes

Source: OSU

The expansion of the accessibility areas also resulted in increased access to health care services, as shown in the following figures. Figure E. 17 shows the number of health care service businesses accessible post-treatment (all modes) compared with those accessible pre-treatment. Figure E. 18 shows the same but for physician's offices only. The number of accessible services increased in both cases for all time periods.

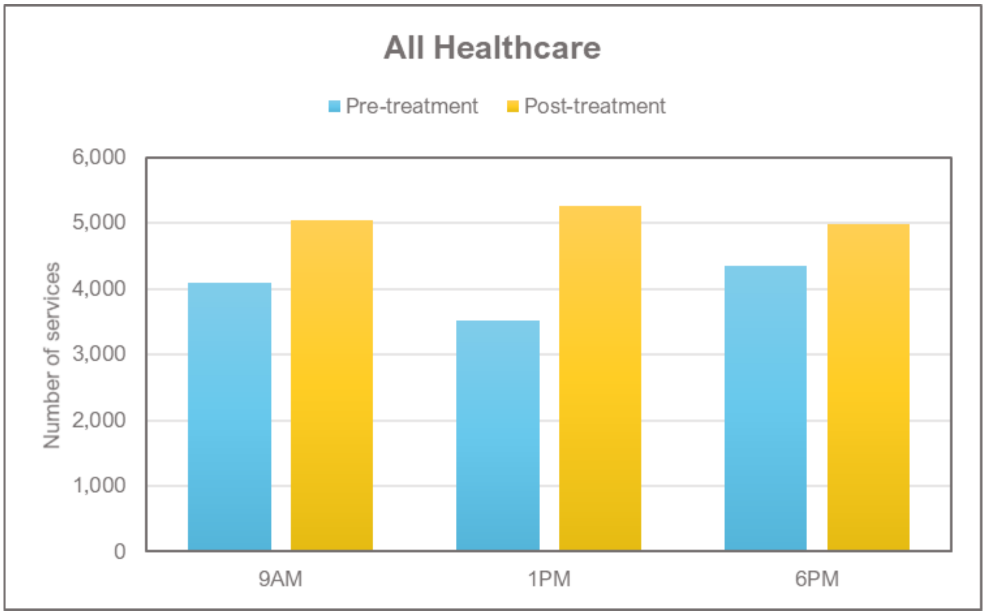

Figure E. 17: All Health Care Accessible Within 30 Minutes

Source: OSU

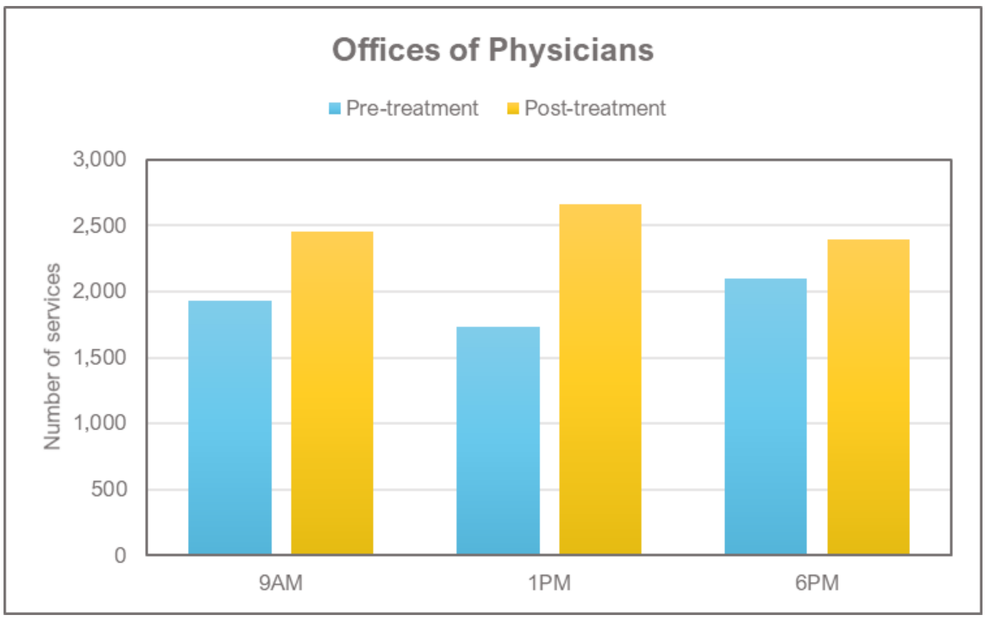

Figure E. 18: Physician's Offices Accessible Within 30 Minutes

Source: OSU

To better emphasize the change, **Figure E. 19** and **Figure E. 20** express the change in accessibility in net terms. The increase in accessible health care services ranged from approximately 14.1% to 49.3% depending on time period. The 1pm time period experienced the greatest gains overall with a gain of over 1,730 facilities of any type. The 6pm time period experienced the least gains at just over 630 facilities of any type. Physician's offices experienced a relatively greater change than health care services overall for all time periods except 6pm, in which case the accessibility increase for physician's offices was comparable to but slightly less than the accessibility increase overall.

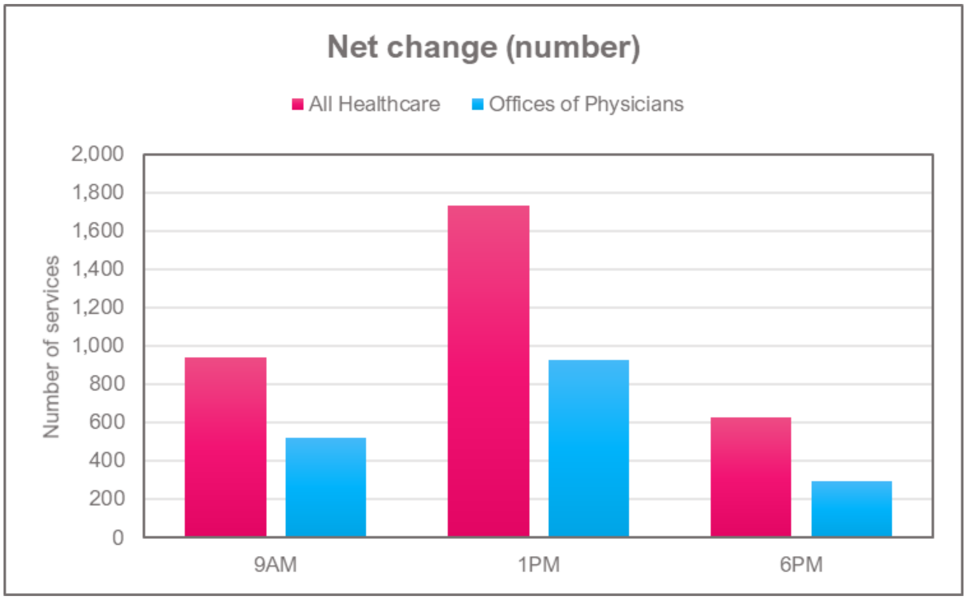

Figure E. 19: Net Absolute Change in Health Care Services Accessible Within 30 Minutes

Source: OSU

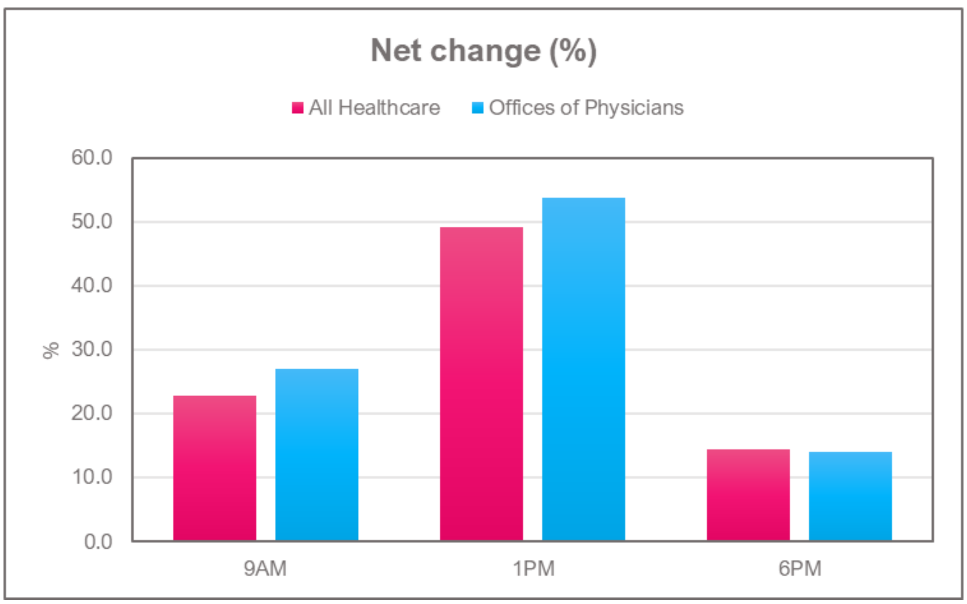

Figure E. 20: Net Percent Change in Health Care Services Accessible Within 30 Minutes

Source: OSU

E.2.4 Conclusions

One of the stated goals of the Smart Columbus Program was to encourage travelers to use multimodal transportation. The program took a multi-pronged approach to this objective, including provisioning of services (e.g., CEAV), providing connectivity between services (e.g., SMH), and providing information about services (e.g., MMTPA). This analysis considered the latter, or specifically how the introduction of Pivot, would affect the ability of a hypothetical traveler departing from Linden to access jobs and health care services at several times throughout the day constrained by a travel time budget of 30 minutes. The accessibility area reachable in this time budget was computed for the pre-treatment case where the traveler could plan trips using only the bus and walking, as well as the post-treatment case where the traveler could plan trips using these modes plus several rented micromobility options including bicycles and scooters. The number of jobs and health care services in the accessibility area were counted for each case, and the difference between the two cases represents the hypothetical accessibility change that resulted from the introduction of Pivot.

The analysis revealed that the multimodal trip planning capability provided by Pivot resulted in an expansion of the 30-minute accessibility area reachable by a hypothetical traveler departing the Linden Transit Center. As a result of the expansion, the traveler would be able to reach at least 20,000 additional jobs and 3,000 additional health care services than they would using the trip planning tools that existed prior to the introduction of Pivot. The increase in accessibility was even greater for certain classes of jobs and services and at certain times of day.

It is important to note that this analysis is primarily focused on the impact of improved access to information, specifically trip planning information afforded by Pivot, rather than on access to multimodal transportation services themselves. All of the transportation services included in the analysis exist independently of Smart Columbus, and the allocation of these services is also independent of Smart Columbus except for the additional CoGo stations introduced in conjunction with the SMH facilities. While it is theoretically possible for a traveler to achieve the accessibility gains observed in the analysis by manually integrating trip plans for various services, this would be impractical for most travelers due to the time cost involved and the complexity of integrating the various sources of information. Therefore, it is the *information* provided by Pivot that produces the increase in accessibility rather than the existence of the transportation services themselves.

The accessibility analysis focused on the Linden neighborhood and within the study region of the CMAX corridor. It is also important to note that the Pivot has potential impacts on access to jobs, health care and other community resources across the entire region.

E.2.5 References

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E.3 SMART MOBILITY HUB EVALUATION: HOUSING MARKET SUPPLEMENTARY MATERIAL

E.3.1 Overview

The bundle of improvements provided by SMHs can work to enhance transit functionality via informed trip planning, connect residents to digital services via public wi-fi, and provide a reliable location for micromobility options. These can improve accessibility of areas served by SMHs, especially for residents reliant on public transportation. Given that most of these benefits accrue to those living close or interacting with the SMHs, there is the potential for SMH improvements to affect nearby property markets. Enhanced mobility is desirable, and this makes SMH-treated neighborhoods relatively more attractive to live in. Neighborhood improvements can also act as a signal for future investments by private and public actors. This may result in increased purchases and increases in housing prices as buyers expect future price appreciation in treated neighborhoods.

It is reviewed to see if SMH-adjacent neighborhoods display new housing market activity relative to similar neighborhoods. This can inform as to whether SMHs act as a trigger for changes that affect the economic and demographic composition, and therefore the beneficiaries, of nearby neighborhoods. While not directly related to the mobility or customer service outcomes explored in the PfMP, these results provide context for how neighborhoods may evolve in the future. The spatial variation is used in access to SMHs and estimate a difference in differences (DiD) model using two different approaches for imputing counterfactual neighborhood housing outcomes. A sizeable effect of SMHs was found on short-run market activity that implies a 33.5% increase in sales likelihood for residential parcels. However, mixed evidence of any appreciation or depreciation of housing prices was found and is due to SMHs across two modeling approaches.

It is difficult to identify how these factors are playing out in property markets due to the short timeframe after SMH installation. Delays and disruptions resulting from COVID-19 imply a post-launch period of less than a year, meaning that residents, renters, homebuyers, and landlords are likely still familiarizing themselves with the new services and their associated effects on accessibility. Future work will explore the robustness of these findings and examine longer-run trajectories in treated neighborhoods.

E.3.2 Summary of Findings

E.3.2.1 DATA

The sample is composed of parcels and housing transactions in selected neighborhoods from 2016-March 2021. This analysis relies primarily on publicly available property data from the Franklin County Auditor's Office ad all arms-length transactions, removing any non-market transfers from the dataset are used. The baseline (2016) land parcel database was used to identify geocoded residential parcels within the neighborhoods of interest. The up-to-date sales file from mid-March 2021 is merged to this parcel database, giving a complete dataset of residential properties and sales. Neighborhoods are described using data on transit stations, land use, and socioeconomic characteristics. The baseline demographic and economic composition of neighborhoods is categorized with data from the 5-Year American Community Survey for years 2012-2016. Data on transit station locations and corresponding ridership at each station is provided by COTA's open data platform and land use surrounding each transit station location is defined using the baseline parcel data from the Auditor's office.

E.3.2.2 METHODOLOGY

The focus is on two housing market outcomes and are outlined in this report; sales activity and housing prices. First was to test whether residential parcels in SMH adjacent neighborhoods are more likely to be sold compared to similar neighborhoods. Secondly, to explore whether SMH benefits have capitalized into neighborhood housing prices by estimating a hedonic model of housing prices. Increased market activity in treated neighborhoods suggests that home buyers and sellers are adjusting to the new mobility services and the associated shifting of neighborhood expectations. Higher housing prices indicate that buyers are bidding higher to live nearby the enhanced amenities. Over time, increased activity can be expected and can result in higher prices, but this need not immediately occur.

To isolate the effects of SMHs, counterfactual locations should be constructed to compare to SMH-treated neighborhoods and rely on the fact that five out of six SMH are installed directly nearby existing COTA transit stops. COTA stations are used along frequently served bus lines as central points and generate a sample of potential counterfactual neighborhoods surrounding these points; stations without shelters and with low ridership are removed from consideration. Neighborhoods are proxied by creating half-mile distance buffers surrounding transit stations, with residential tax parcels within these buffers assigned to a transit station-centered “neighborhood”. Similar strategies have been used to identify the local effects of new housing supply (Asquith et al 2021; Damiano and Frenier 2020; Li et al 2019), affordable housing construction (Diamond and McQuade 2019), and rent control policies (Autor et al 2014), among other types of policy interventions. SMHs at Easton and Columbus State Community predominantly serve non-residential areas, so the focus is on three SMH installations along Cleveland Avenue (see **Figure E. 21**).

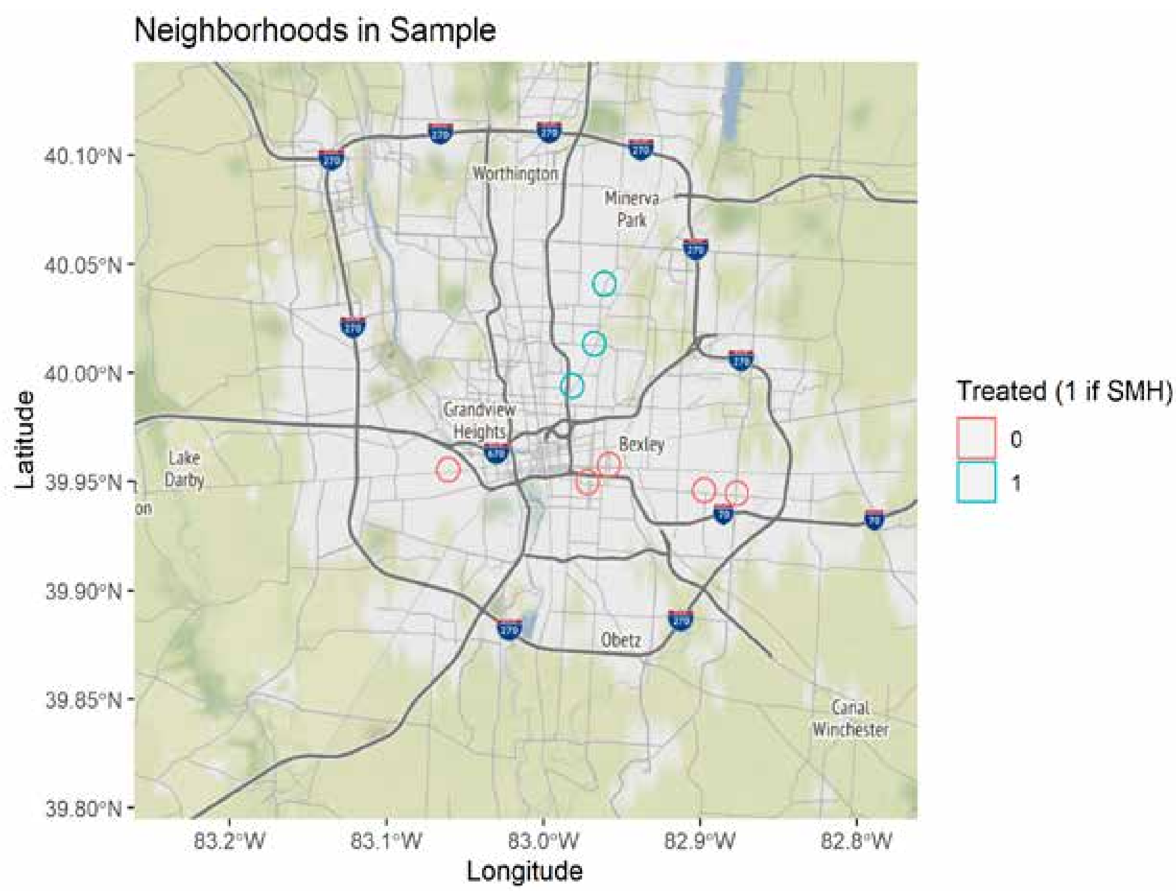

Figure E. 21: Illustration of SMH and Counterfactual Neighborhoods

Source: OSU

A sample of transit station-centered counterfactual neighborhoods is constructed similar to those with SMHs in surrounding land use, demographic characteristics, and transit ridership. This is achieved by estimating propensity scores (or similarity scores), a measure of the likelihood of receiving a given treatment, for all potential neighborhoods and filtering out neighborhoods with low similarity to three SMH-neighborhoods. After filtering out overlapping "neighborhoods", a final sample of five control neighborhoods and three treatment neighborhoods are used. Treatment is conceptualized as being a residential parcel (or housing transaction) in a transit-centered neighborhood augmented by a SMH after 2020. While SMHs were not brought fully online until late summer 2020, announcement of the locations and construction began and were completed by winter 2020. **Table E. 9** and **Table E. 10** describe the variables included in the analysis and compare these across treatment and control groups for market activity and hedonic samples.

A DiD strategy is used to isolate the effects of SMH investments on the two outcomes of interest. The key assumption underlying this approach is that any post-treatment changes in outcomes of interest in treated neighborhoods relative to control neighborhoods can be attributed to SMHs, after controlling for parcel-level characteristics, time, and neighborhood averages.

The two outcomes for the following models are estimated separately (transactions and housing prices). For residential market activity, the sample is a balanced panel of residential parcels from 2016-March 2021 and the following equation is used for analysis:

The variable is an indicator for whether a sale is observed for parcel in neighborhood in year . is an indicator for whether parcel is in a treated neighborhood after treatment (e.g. 2020 and beyond). is a matrix of parcel-level characteristics, such as the number of residential units in the structure and its age. and are fixed effects (e.g. group averages) for neighborhoods and years respectively. The parameter of interest is which is the DiD coefficient used. This is loosely interpreted as the approximate percentage increase in the probability of observing a sale after the introduction of a SMH and a similar model is estimated for housing prices.

The estimating sample is a pooled cross-section of housing transactions in treatment and control neighborhoods from 2016-March 2021. These two models differ in the structure of the sample and the outcome of interest, but are reliant on the same DiD strategy.

E.3.2.3 SUMMARY OF RESULTS

In summary, the results suggest a sizeable increase in sales activity in SMH-adjacent neighborhoods, but no evidence of any capitalization of these SMHs into housing prices. It is found that SMH installation has increased the probability of a parcel selling in treated neighborhoods by 2.03%. Given the sample average sale probability of 6.06%, this corresponds to a 33.5% increase in the likelihood of sale due to SMH installation. Alternatively, the results of the hedonic model provide no evidence of any price appreciation, though these estimates are imprecise in part due to the small post-treatment sample size.

Table E. 7: DiD Model Outcomes for Housing Market

	Market Activity (1 if Sold)	Housing Price (Log Price)
Treatment	0.020 (0.008)**	0.104 (0.088)
Num.Obs.	40122	2724
R2	0.020	0.326
R2 Adj.	0.019	0.320
Each model includes structure age, age squared, acreage, square footage, rooms, bedrooms, baths, and building units. Fixed effects for neighborhood and year. Standard errors clustered at the level of treatment (neighborhoods)		

Source: OSU

Recent public investments into treated neighborhoods, including the introduction of a new bus rapid transit line (CMAX), may threaten to violate the assumptions of the DiD model used for this analysis. While these investments predate treatment, they may change neighborhoods in ways that create differential trends between neighborhoods similar in the baseline period (e.g. 2016). To check the robustness of findings from this analysis, a similar analysis is ran using a sample of parcels along the CMAX corridor. While treated neighborhoods are defined similarly, control parcels are those within a half mile of the CMAX Corridor, but not within a half mile of an SMH. In this case, all properties in the sample are exposed to CMAX improvements, as well as other neighborhood investments or initiatives.

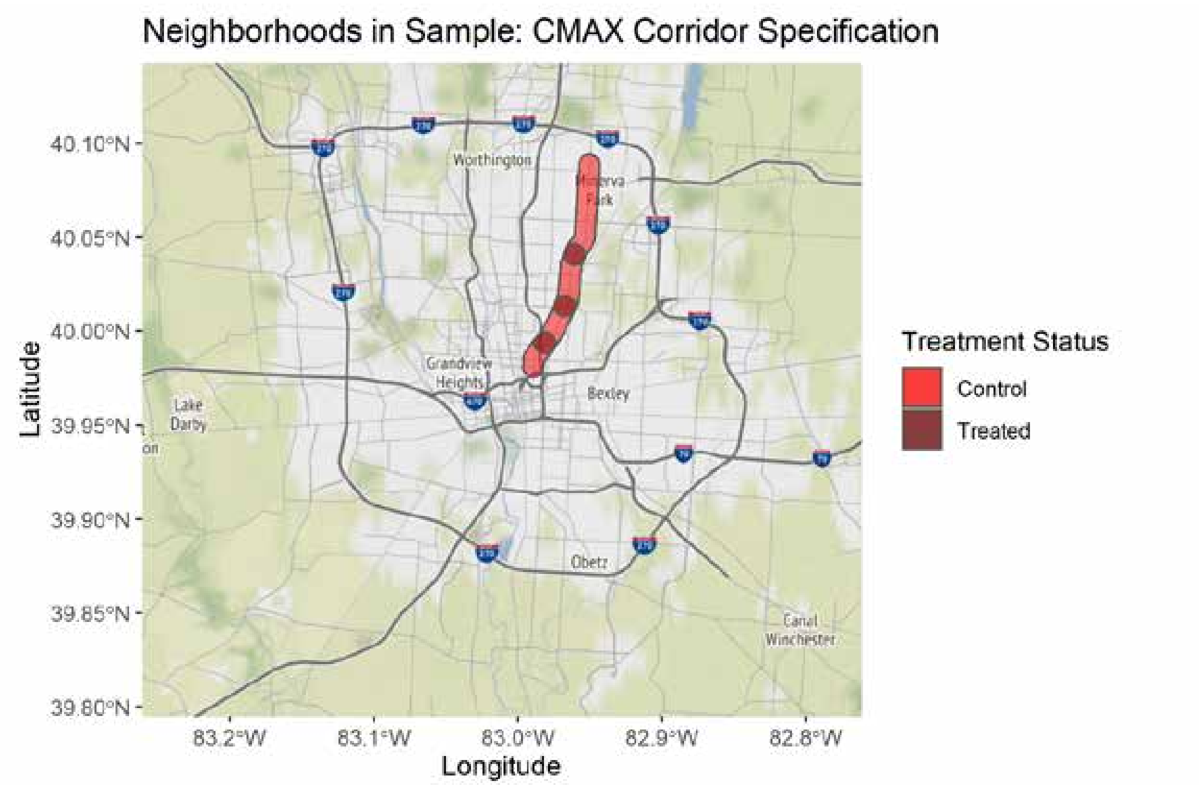

Figure E. 22: Illustration of SMH and Counterfactual in CMAX Robustness Check

Source: OSU

For market activity, similar results using the CMAX corridor sample are found (see **Table E. 8**), though coefficients are slightly smaller in magnitude. In this CMAX corridor specification, it is found that SMH installation has increased the probability of a parcel selling in treated neighborhoods by 1.50%, corresponding to a 25% increase in the likelihood of sale. Consistency across the two different approaches suggests that SMHs have increased market activity in nearby neighborhoods. In addition, the CMAX-only specification suggests a sizeable capitalization of SMHs into housing prices of 17%. Taken together with the results from the previous specification, there is some evidence of moderate house price appreciation resulting from SMH investments in treated neighborhoods, though this is inconclusive.

This increase in market activity warrants future research examining how the SMH-treated neighborhoods evolve over time. Increased activity can be an indicator of stimulated investment into the neighborhood, but can also be a leading indicator of neighborhood change and gentrification, changing the composition of who benefits from the policy. Neighborhoods with SMHs are poorer, with high percentages of renters and minority residents. While new investment in housing and property can be a boon to homeowners, the benefits of the SMH and the increased value of local housing may not extend to poorer residents who rent. A key limitation of this study is the lack of data on residential rents. These may be more responsive to the amenity benefits of the SMHs versus the long-term expectations of homeowners and investors. Future research will focus on housing improvements, neighborhood composition, and the types of buyers contributing to this increase in market activity.

Table E. 8: DiD Model Outcomes for Housing Market: CMAX Corridor

	Market Activity (1 if Sold)	Housing Price (Log Price)
Treatment	0.015 (0.005)***	0.178 (0.072)**
Num.Obs.	52464	2690
R2	0.011	0.338
R2 Adj.	0.010	0.332

Note: Each model includes structure age, age squared, acreage, square footage, rooms, bedrooms, baths, and building units, as well as neighborhood characteristics percentage black, median household income, owner occupancy rate, percentage of residents with a college degree, and population density. Heteroskedasticity-consistent standard errors. Sample mean likelihood of sale in a year is 6%, implying a 25% increase in sales likelihood for treated parcels. Mean housing price in the sample is $118,225, implying a capitalization effect of $20,103 from SMH investment.

Source: OSU

E.3.2.4 REFERENCES

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Table E. 9: Market Activity Sample Characteristics

	Control (N=27498)		Treatment (N=12696)		Difference in Means	Standard Error
	Mean	Std. Dev.	Mean	Std. Dev.		
Parcel-Level Characteristics						
SalesIndicator	0.1	0.2	0.1	0.2	0.0	0.0
Units	1.2	0.4	1.1	0.3	-0.1	0.0
Rooms	6.7	2.1	5.8	1.8	-0.9	0.0
Baths	1.6	0.7	1.3	0.5	-0.3	0.0
Basement	0.9	0.4	0.9	0.3	0.0	0.0
nStories	1.6	0.5	1.5	0.5	-0.1	0.0
Age	83.2	25.1	78.4	18.7	-4.8	0.2
StructureArea	1518.4	607.8	1195.1	409.6	-323.3	5.2
LandArea	6030.5	3786.0	6020.3	3833.3	-10.1	41.0
Neighborhood-Level Characteristics						
StationRidership	108.6	40.7	247.7	54.8	139.0	0.5
PctResidential	0.7	0.1	0.6	0.2	-0.1	0.0
PctBlack	0.5	0.2	0.6	0.1	0.1	0.0
LogMedHHIncome	10.5	0.1	10.3	0.1	-0.2	0.0
PctOwnOcc	0.4	0.1	0.4	0.1	0.0	0.0
MedianAge	33.8	2.1	30.2	4.0	-3.6	0.0

Source: OSU

Table E. 10: Hedonic Model Sample Characteristics

	Control (N=2015)		Treatment (N=719)		Difference in Means	Standard Error
	Mean	Std. Dev.	Mean	Std. Dev.		
Parcel-Level Characteristics						
Price_2020USD	124350.6	109822.0	65582.8	70224.7	-58767.8	3583.9
Units	1.2	0.5	1.1	0.4	-0.1	0.0
Rooms	7.0	2.3	6.1	2.1	-0.9	0.1
Baths	1.6	0.7	1.3	0.5	-0.3	0.0
Basement	0.9	0.3	0.9	0.3	0.0	0.0
# Stories	1.8	0.4	1.6	0.5	-0.1	0.0
Age	90.4	23.2	80.6	18.1	-9.7	0.9
StructureArea	1603.0	587.4	1238.6	441.8	-364.4	21.0
LandArea	5421.8	1857.3	5610.7	2631.9	188.9	106.5

	Control (N=2015)		Treatment (N=719)		Difference in Means	Standard Error
	Mean	Std. Dev.	Mean	Std. Dev.		
Neighborhood-Level Characteristics						
StationRidership	102.6	30.1	250.3	50.1	147.7	2.0
PctResidential	0.7	0.1	0.6	0.2	-0.1	0.0
PctBlack	0.5	0.2	0.6	0.1	0.1	0.0
LogMedHHIncome	10.4	0.1	10.3	0.1	-0.2	0.0
PctOwnOcc	0.4	0.1	0.4	0.1	0.0	0.0
MedianAge	33.0	1.8	30.1	3.7	-3.0	0.1

Source: OSU

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