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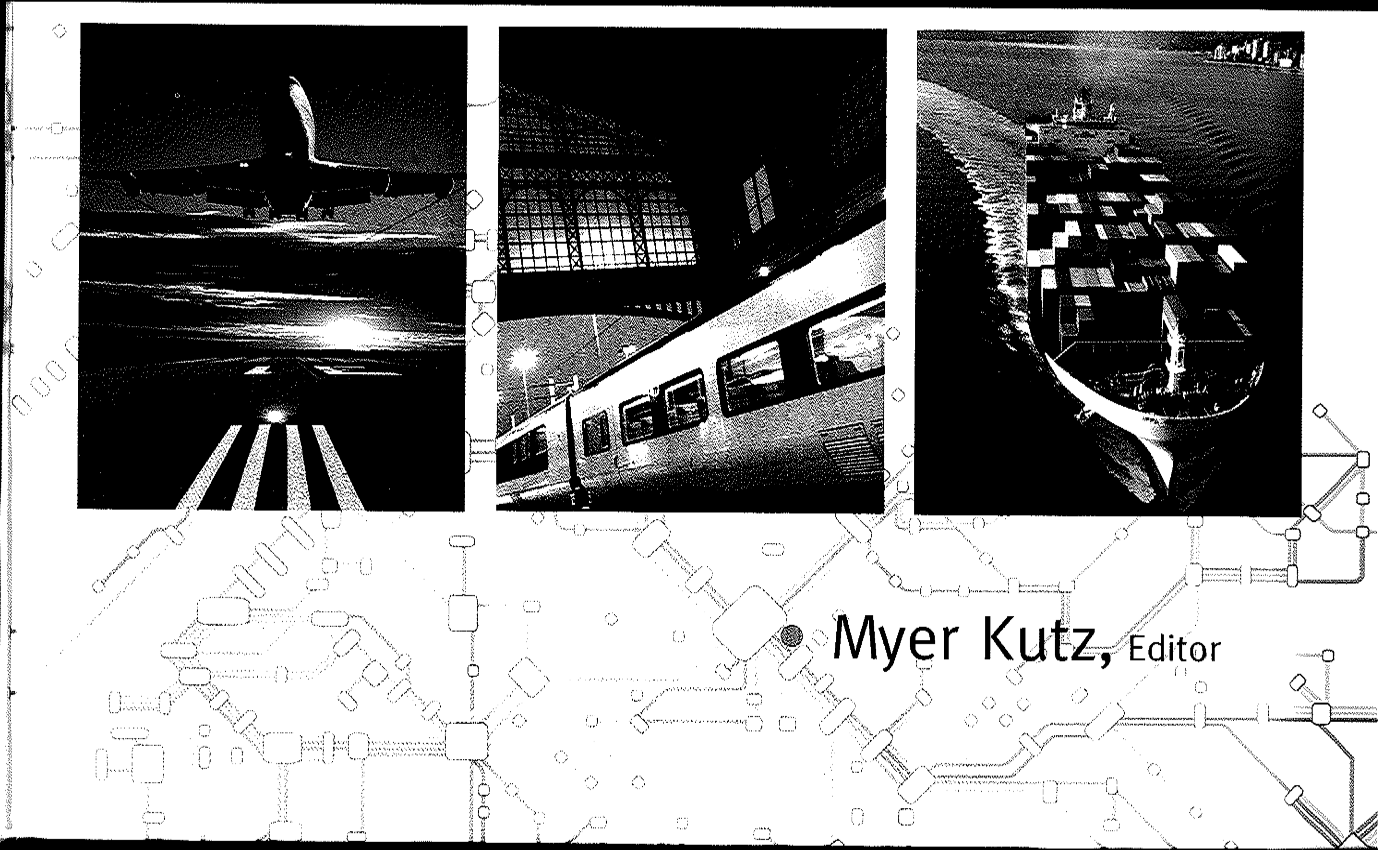

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PREFACE

Volume II of the Second Edition of the *Handbook of Transportation Engineering* focuses on applications and technologies. It is divided into three parts:

Part I: Automobile Transportation: Traffic, Streets, and Highway, which contains 15 chapters
Part II: Non-Automobile Transportation, which consists of 11 chapters
Part III: Safety, Noise, and Air Quality, which contains 9 chapters

Of the 35 chapters in Volume II, 13 are entirely new to the handbook, 12 have been updated from the first edition, and 10 are unchanged. The purpose of these additions and updates is to expand the scope of the parts of the volume and provide greater depth in individual chapters.

The 13 new chapters in Volume II are

Chapter 2: Traffic Origin-Destination Estimation
Chapter 8: Roadway Transportation Lighting
Chapter 11: Pavement Engineering I: Flexible Pavements
Chapter 12: Pavement Engineering II: Rigid Pavements
Chapter 14: Modern Bridge Engineering
Chapter 15: Tunnel Engineering
Chapter 18: The Spectrum of Automated Guideway Transit (AGT) and Its Applications
Chapter 25: Maritime Transport and Ship Design
Chapter 26: Oil and Gas Pipeline Engineering
Chapter 29: Hazardous Materials Transportation
Chapter 31: Security and Survivability of Surface Transportation Networks
Chapter 32: Optimization of Emergency Evacuation Plans
Chapter 35: Climate Change and Transportation

The 12 chapters that contributors have updated are

Chapter 1: Traffic Engineering Analysis
Chapter 3: Traffic Congestion
Chapter 4: Highway Capacity
Chapter 5: Traffic Control Systems: Freeway Management and Communications
Chapter 6: Traffic Signals
Chapter 7: Highway Sign Visibility
Chapter 9: Geometric Design of Streets and Highways
Chapter 10: Intersection and Interchange Design
Chapter 16: Pedestrians
Chapter 30: Incident Management

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CHAPTER 18

THE SPECTRUM OF AUTOMATED GUIDEWAY TRANSIT (AGT) AND ITS APPLICATIONS

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18.1 INTRODUCTION

Automated guideway transit (AGT) is no stranger to the transportation community or to anyone who has recently traveled through large airports, visited cities with downtown people movers (DPMs), or vacationed at amusement parks where monorail trains shuttle visitors around the sprawling resorts. At the turn of the 21st century, while modern communication technology has brought consumers WiFi, Bluetooth, and other high-tech gadgets, the transportation community has its aspirations on the driverless transit: a spectrum of AGT systems, such as automated people movers (APMs), downtown people movers (DPMs), group rapid transit (GRT), driverless metros (DLMs), and personal rapid transit (PRT).

According to the latest tally (Fabian 2010), there are 150 applications along the various spectra of AGT technologies around the world. After more than four decades of emerging and developing processes, the AGT technology is no longer limited to airport use as shuttles or circulators. It has expanded to downtown and metropolitan areas as major activity center circulation and public transit systems. Another surging presence of AGT applications was observed in various leisure and recreation facilities and private and public institutions. As shown in Figure 18.1, overall, AGT applications are almost equally distributed among airports, urban centers, and institutions.

While the general public may be familiar with automated people movers (APMS) and label anything that moves people, including elevators and moving walkways, as people movers, the term preferred by transit professionals is *automated guideway transit* (AGT). Updating the original AGT definition (US Congress, Office of Technology Assessment 1975), AGT is defined as a class of transportation systems in which fully automated vehicles operate along dedicated guideways. The capacities of the AGT vehicles range from 3 or 4 up to 100 passengers. Vehicles are made of single-unit cars or multiple-unit trains. The operating speeds are from 10 to 35 miles per hour (mph), and headways may vary from a few seconds to a few minutes. The guideway system may be made of a single trunk route, multiple branches, or interconnected networks.

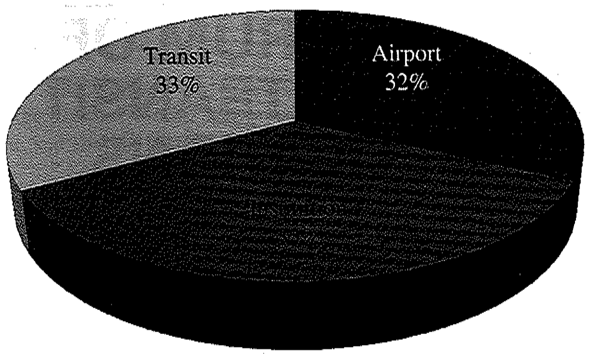


FIGURE 18.1 Distributions of APM applications. (*Source:* Based on data by Fabian 2010.)

18.2 DEFINITIONS

If the preceding definition is a simple, straightforward, and no-frills label for the AGT family, each individual member of the family deserves certain elaboration. Depending on the vehicle size, capacity, and other operating characteristics, AGT may be categorized into various subgroups, such as automated people movers (APMs), group rapid transit (GRT), and personal rapid transit (PRT). Different operating environments often give AGT applications generic names, such as airport circulators, downtown people movers, driverless transit (DLT), or driverless metros (DLM). Diversified track configurations, propulsion powers, and other technological features impart to AGT other names, such as monorail, duorail, and maglev, among others.

AGT systems are different from traditional heavy, light, and commuter rail transit in that they are operated via a central control system without drivers, conductors, or station attendants. Usually AGT systems use narrower right-of-ways, lighter tracks, if any, and smaller vehicles than traditional transit applications. The improved communication and control technology has enabled fully automated, driverless, fail-safe operations of modern AGT to satisfy wider ranges of capacity, spatial coverage, and temporal span of transit services.

As the first effort to provide a consensus definition for the spectrum of AGT technologies in the 21st century, this chapter will provide a brief review and some definitions for each subcategory of the AGT family. The main content of this chapter will focus on APMs and PRT, the two brightest stars of the AGT family. The APM category is important because of its multiple worldwide applications, and the ever-increasing PRT promises that it may be able to combine the advantages of both private automobiles and public transit.

18.2.1 Automated People Movers (APMs)

According to the General Accounting Office (GAO 1980), APMs are driverless vehicles operating on a fixed guideway. Vehicle capacities range up to 100 passengers, and vehicles may be operated as single units or as trains at up to 30 mph. *Headway*, the time interval between vehicles moving along a main route, varies from 15 seconds to 1 minute (Liu and Lau 2008). The realistic operating headway may be limited to 1 minute or more; even headways as short as 1 second were reported and tested in various pilot runs. The system is automated in that there are no drivers on board the vehicles or trains. The system is controlled or monitored by operators from a remote central control facility. Typically, the electromechanical design and physical characteristics of an APM are unique and proprietary to each manufacturer (Elliott and Norton 1999).

The first installation of an APM system at a major U.S. airport was at Tampa International Airport in 1971 (Lin and Trani 2000). Today, close to 50 APM applications can be seen at various airport facilities worldwide, carrying more than 1.6 million passengers daily. Figure 18.2 shows the APM system at Newark Liberty International Airport, one of the early APM applications at the airport, recently renewed and expanded.

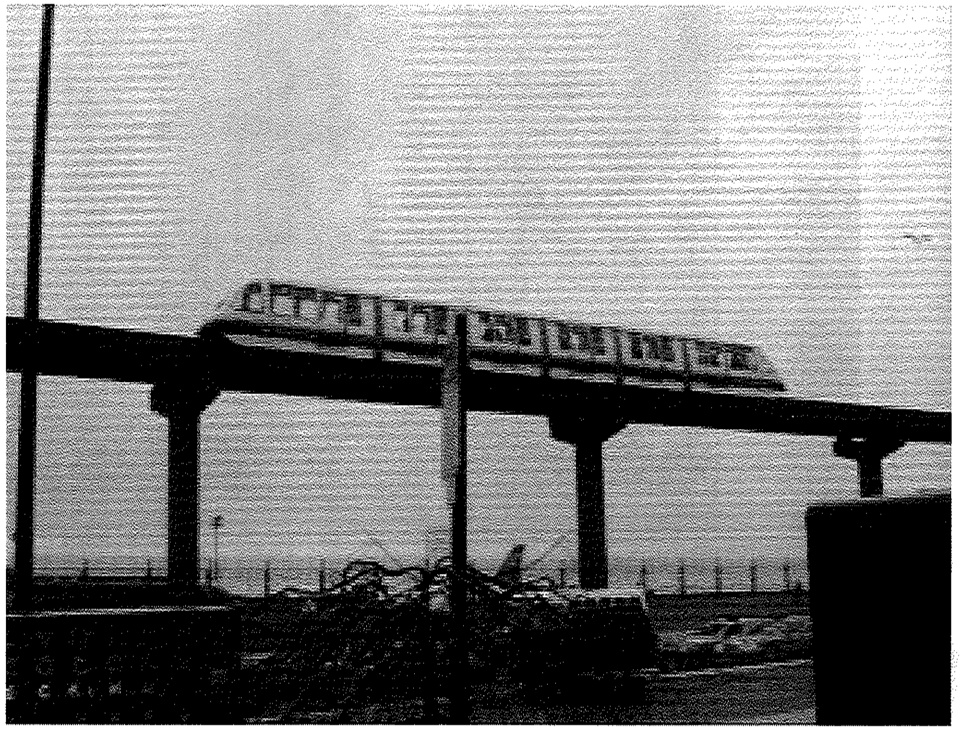


FIGURE 18.2 An example of airport APM, Newark Liberty International Airport, New Jersey.

18.2.2 Personal Rapid Transit (PRT)

If APMs occupy the larger-vehicle spectrum of AGT technology, we can easily place PRT at the other end of the spectrum—very small vehicles with a capacity of three to five persons per car or "pod." Based on definitions in various studies by several authors (Schneider 2008; Muller 2007; Koskinen, Luttinen, and Kosonen 2007; Cottrell 2006; Advanced Transit Association 1988), PRT can be a subcategory of AGT systems that offers on-demand, nonstop transportation using small, automated vehicles on a network of dedicated guideways with off-line stations.

Similar to APM applications, PRT operates automated vehicles along dedicated guideways. In contrast to APMs, PRT vehicles are designed for a single individual or a small group traveling together by choice on a network of guideways, and the trip is nonstop with no transfer. PRT stations are often off-line or bypasses of main lines, so vehicles stop only at their riders' final destination station. PRT trips typically are on-demand, and PRT vehicles or pod cars are supposed to wait at stations prior to the arrival of passengers.

There was strong interest in PRT in the United States during the 1970s (U.S. Congress 1975) when higher gasoline prices and congestion called for more efficient transportation solutions. A PRT application was promoted as the best solution to widespread urban problems in U.S. metropolitan areas. With a much narrower footprint in the right-of-way, smaller vehicles, lighter tracks, and tighter headways, PRT promised to provide a higher level of services with less expensive infrastructure. However, there are still no applications in the United States after its conceptual introduction more than four decades ago.

A number of factors, including political, economic, and technical, jeopardized the initial objectives of the demonstration project. The intended PRT demonstration project in Morgantown, West Virginia, turned out to be a group rapid transit (GRT) application with much higher cost and less

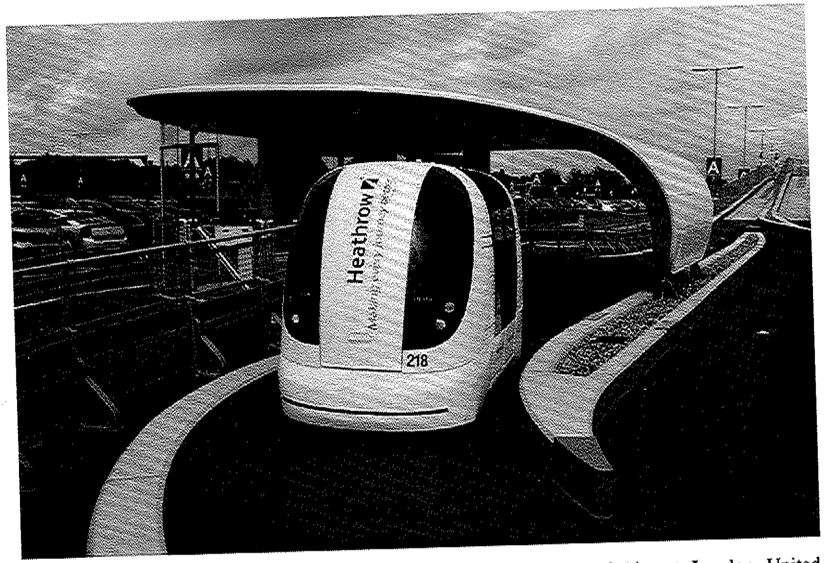


FIGURE 18.3 An example of PRT: ULTRa at Heathrow International Airport, London, United Kingdom. (*Source:* www.atsltd.co.uk, 2010.)

applicability in other places. Starting at the turn of the 21st century, some renewed interest in PRT has spurred a series of feasibility studies and a demonstration project in Heathrow Airport in London, United Kingdom, as shown in Figure 18.3.

18.2.3 Group Rapid Transit

After defining both ends of the AGT spectrum, APM and PRT, it is much easier to envision the middle child—*group rapid transit* (GRT)—which is similar to PRT but with higher-occupancy vehicles and grouping of passengers with potentially different origin–destination pairs. As noted in an early study (U.S. Congress 1975), the starting capacity for GRT is 6 passengers per car, whereas the upper limit is around 16 or 18; there are no clear distinctions between GRT and APMs in terms of vehicle capacities.

As the capacity difference blurs between APMs and GRT, it is possible for a GRT system to have a range of vehicle sizes to accommodate different passenger loading requirements. For example, at different times of the day or on routes with less or more average traffic, a GRT system may constitute an "optimal" surface transportation routing solution in terms of balancing trip time and convenience with resource efficiency. On the other hand, the dynamic coupling may bring complications to the operation processes that have to be evaluated for tradeoffs based on individual entities when such demand arises.

The Morgantown application in West Virginia should be correctly classified as GRT, and it is the only GRT application in the world, even though it is often mislabeled as PRT or an APM. As shown in Figure 18.4, the Morgantown GRT vehicle has seats for 8 people and some room for standees. The cars run on rubber tires in a U-shaped concrete guideway that has power and signal rails along the inner walls. The system is fully automated and does not require human drivers. There are three intermediate stations. Each station has several platforms and also "express tracks" that bypass the station completely.

The Morgantown GRT does not meet the qualifications of PRT because it does not provide nonstop services for a small group of passengers. It does not belong to the APM group, in a more strict definition, owing to its smaller vehicles with limited capacities. Whereas PRT provides nonstop service, GRT carries a larger group of people and stops at multiple requested destinations. In a perfectly parallel world, PRT can be compared with a taxi and an APM with a bus, which leaves no option but to put GRT into the *paratransit* group (Panayotova 2009).

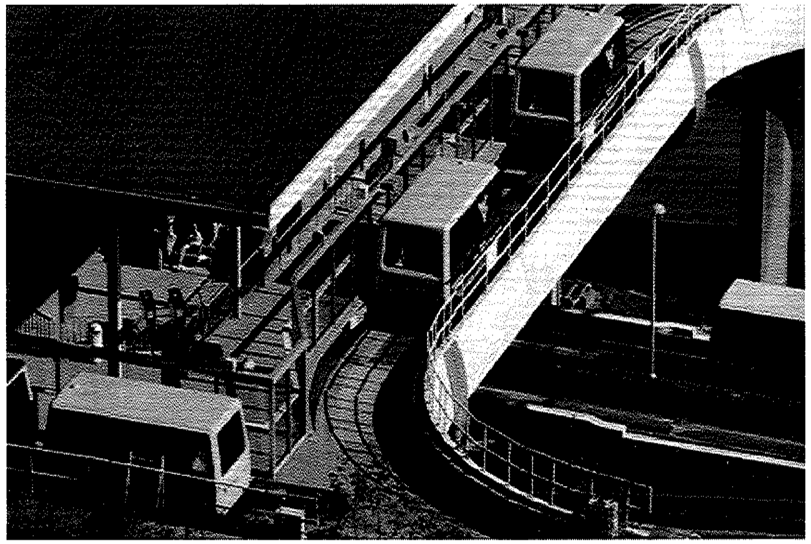


FIGURE 18.4 An example of GRT, Morgantown, West Virginia. (*Source:* West Virginia University 2009.)

18.3 HISTORICAL DEVELOPMENT

Despite the many versions of how AGT systems began, the widely accepted origin of modern AGT has been documented definitively by Fichter (1964). After a brief review of "metropolis centers" and their associated circulation challenges, Fichter introduced the concept of "individualized automated transit," that is, an automated "small car" operating along "small exclusive trafficways" within street right-of-ways. With these descriptions and elaborate vehicle control and network layout, a vivid idea of PRT was born in the United States in the 1960s.

Another group of AGT applications, such as Skybus by Westinghouse Electric Corporation and Peoplemover by Goodyear Tire and Rubber Company, was the baby step taken by the private sector toward modern types of APM applications. AGT technology gained momentum during the 1970s when the Urban Mass Transportation Administration (UMTA), the predecessor of the Federal Transit Administration (FTA) today, signed a contract with West Virginia University to construct the first automated guideway transit (AGT) in the United States (Schneider 1999). Since then, the true markets for driverless metros emerged and grew overseas, whereas airport applications blossomed in the United States.

The following section provides an overview of the historical development of DPMs, APMs, and PRT. While there are a large number of institutional AGT applications around the world, there is little information on the historical background owing to the small scale and private nature of the projects; some of the historical development was intertwined with the general development of AGT applications.

18.3.1 Downtown People Movers (DPMs)

Burdened by increasing transit operating deficits, traffic congestion, and associated air pollution problems, the UMTA turned its hope to the emerging technology, AGT, a future transportation promise. In 1971, the UMTA funded four companies at $1.5 million each to demonstrate its AGT development at a transportation exposition, TRANSPO 72, held at Dulles International Airport near Washington, DC. As a direct result of TRANSPO 72, a few AGT applications were acquired for airports and zoos.

FIGURE 18.5 Downtown people mover (DPM) in Jacksonville, FL.

In 1975, the UMTA announced its Downtown People Mover (DPM) Program and sponsored a nationwide competition among cities. The UMTA DPM Program offered federal funds for the planning, design, and building of AGT systems as part of the demonstration program. Motivated by the "free" money, the response was almost overwhelming. In 1976, after receiving and reviewing 68 letters of interest and 35 full proposals and making on-site inspections of the top 15 cities, the UMTA selected Los Angeles, St. Paul, Cleveland, and Houston as candidates to develop DPM applications (General Accounting Office 1980). As second-tier backup candidates, Miami, Detroit, and Baltimore were selected to develop DPMs if they could do so with existing grant commitments. Pressured by the House of Representatives and the Senate Appropriations Conference Committee, the UMTA included Indianapolis, Jacksonville, and St. Louis on the backup candidate list.

After many rounds of debates and discussions, most of the DPM selectees later withdrew from the program, but Miami, Detroit, and Jacksonville stayed the course and eventually built DPMs. Figure 18.5 shows the DPM network in Jacksonville, Florida. In retrospect, few would regard the UMTA's DPM program as a "success." Among all the three cities that implemented DPMs, Miami was often criticized for its higher initial unit costs. However, a recent examination (Cottrell 2010) indicated that its ridership and costs closely match the original forecast, especially after the network was expanded to connect with other transit systems as originally planned but implemented at a later stage.

18.3.2 Driverless Metros (DLMs)

While DPM and PRT applications have been riding the roller coaster of novelty thrills, government support, and disappointing implementations in the United States, DLM applications have quietly gained momentum overseas. The initial concept of a fully automated, integrated transit system in Lille, France, was conceived in 1971, almost at the same time that the UMTA initiated its DPM Program. The construction for the Lille Metro started in 1978, and the first line was inaugurated in 1983 (Net Resources International 2010). When the entire 13.5 kilometers of Lille Metro Line 1 was opened in 1985, the driverless transit linked 18 stations and operated between 5 a.m. and midnight with 1.5- to 4-minute headways. Today, the DLM in France covers an impressive 60 stations, expanding from Lille north toward the border of Belgium, as shown in Figure 18.6. Surprisingly, Lille's VAL system has run at a profit since 1989, and despite vandalism and concerns over personal safety, ridership figures remain healthy.

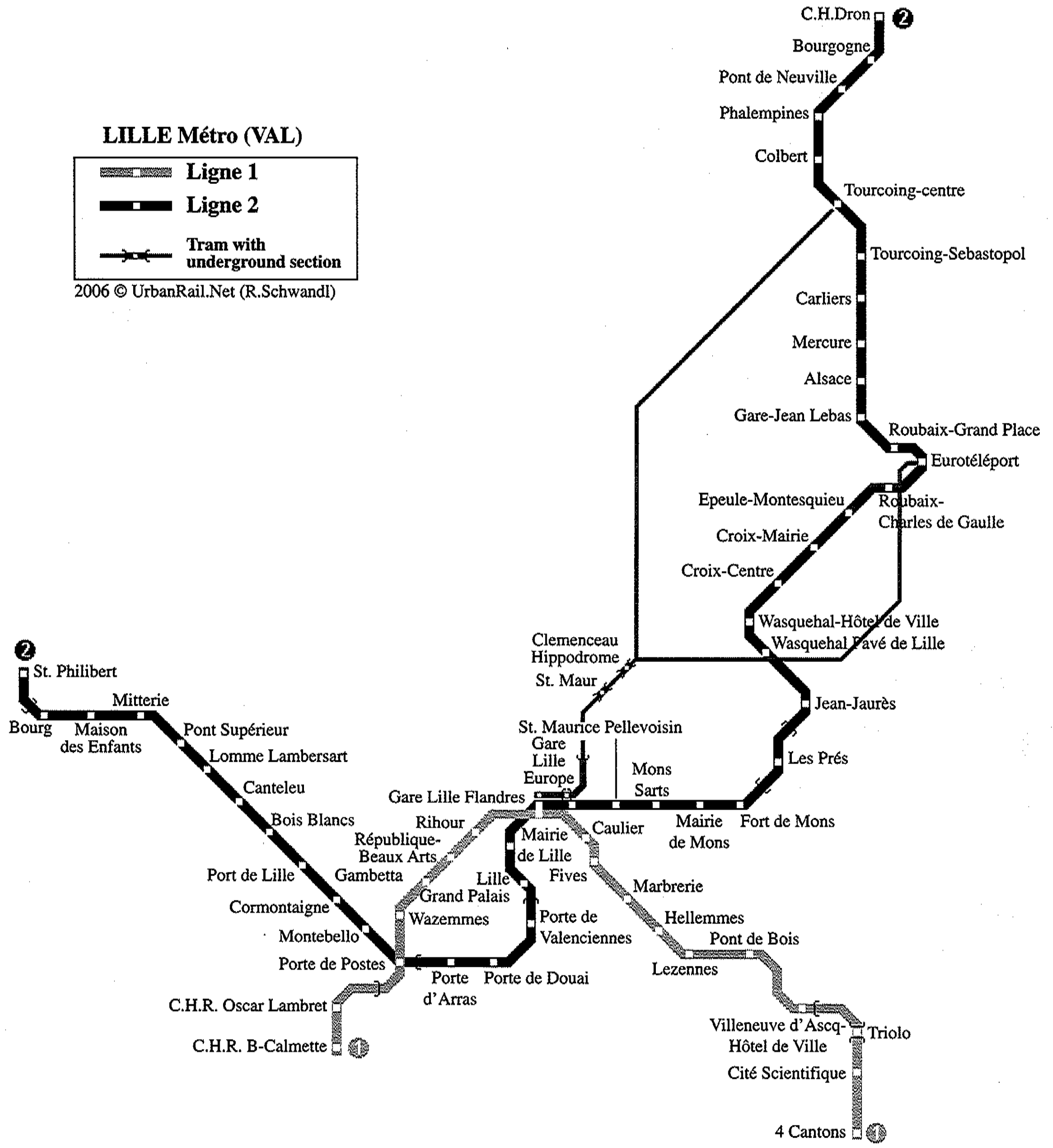


FIGURE 18.6 The Lille Metro Network. (*Source:* Schwandl 2006.)

Not coincidentally, a fully automated GTS was initiated by our northern neighbor, in Vancouver, Canada, in the mid-1980s. The SkyTrain in Vancouver has three branch lines as of the end of 2009:

FIGURE 18.7 SkyTrain in Vancouver, British Columbia, Canada. (*Source:* Jun Suk 2007.)

Expo, Millennium, and Canada Lines. The Expo Line opened in late 1985 in time for the Expo 86 World's Fair (Economic Expert 2010); the Millennium Line opened in 2002; and the newest kid on the block, the Canada Line, opened in 2009 in time for the 2010 Winter Olympics. Together, the three branches of SkyTrain cover almost 60 miles of track that connects almost 50 stations. It provides easy and convenient access to Vancouver International Airport and two international border crossings. Although most of the system is elevated, hence the name SkyTrain, it runs as a subway through downtown Vancouver, as shown in Figure 18.7, and a short stretch in New Westminster.

18.3.3 Airport APMs

Although the birth of APM systems occurred in the 1970s, the past two decades may be labeled as the blossom period, when a large number of airport APM applications in North America were established. As shown in Figure 18.8, after long experience with only a couple of APM systems during the 1970s and 1980s, an increasing number of them have been installed since 1990 and the new millennium. A quick scan of projects under construction or in the planning stages in 2009 revealed that 10 new systems in the United States will have their inaugural runs in the next three years (Liu and Huang 2010).

Given the various sizes and diversified functions of APM services, the scale of airport APMs spans a wide range. As shown in Figure 18.9, the number of stations ranges from 2 to 16, and the length of each system stretches from 2 to 8.1 miles. Despite the turbulence in the airport market in the past decade, airport APMs have become an inherent part of airport expansion plans worldwide (Liu, Gambla, and Huang 2009).

Similar to transit operations, a number of APM systems at airports are operated by the contractors. Documented in a recent survey (Liu, Gambla, and Huang 2009), approximately two-thirds of APM systems at airports in North America are operated by the system suppliers or contractors, such as Otis Elevator Company, DCC Doppelmayer, and Bombardier Transportation, Inc. Only a third of the APMs at airports are operated by the owners of the systems.

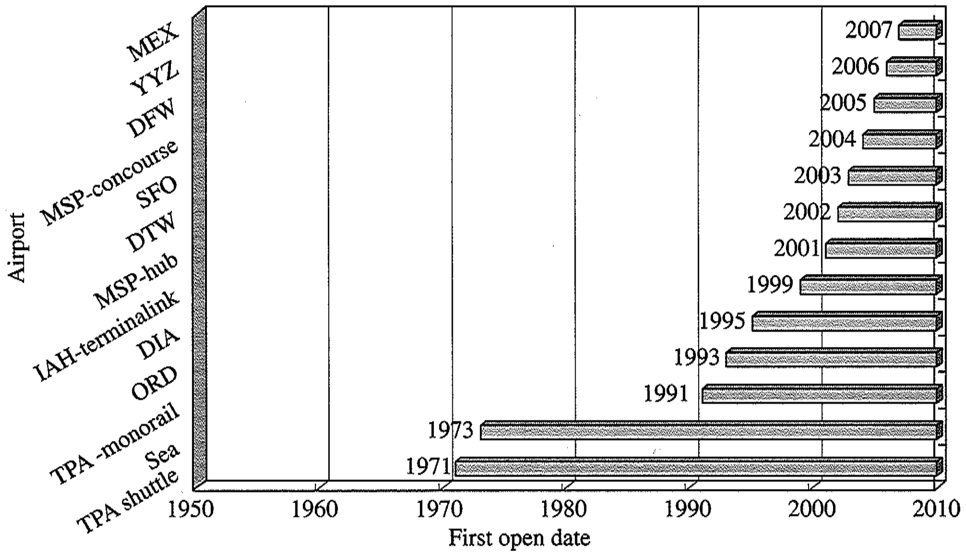


FIGURE 18.8 Operating history of selected airport APMs in the United States.

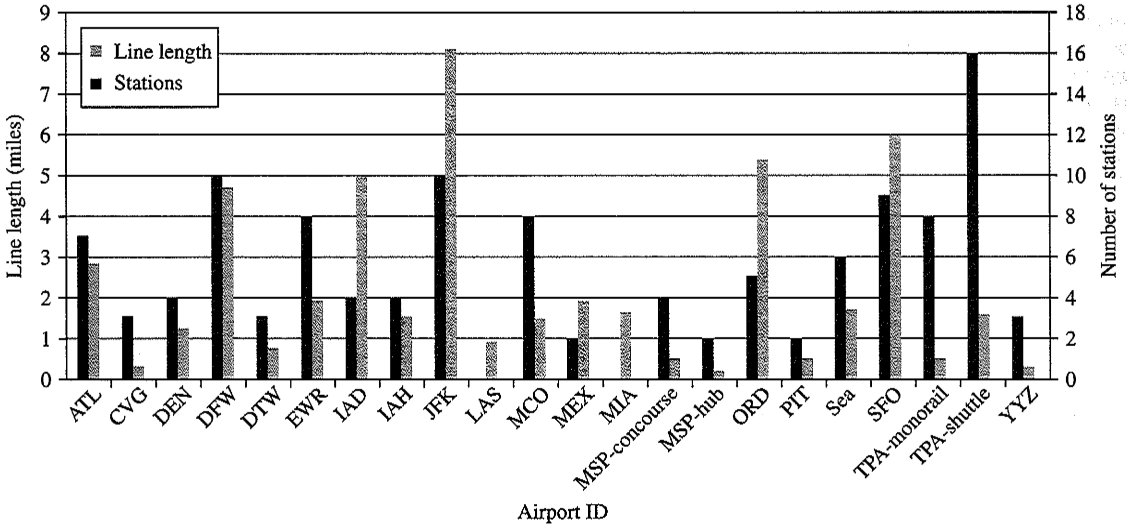


FIGURE 18.9 Scales of selected APM systems at airports.

18.3.4 Personal Rapid Transit

Personal Rapid Transit (PRT) has a long conceptual development history starting approximately in the 1950s. One of the early innovators was Donn Fichter, whose Veyar system was a very small one-person vehicle on a very lightweight elevated infrastructure. Its costs were low enough to enable more miles of network to be installed to make the system accessible to many using only captive single-mode cars. This system was not developed and was criticized for low capacity and an inability to handle group travel such as parents with children.

In 1953, a system called Monocab was conceived as a six-passenger vehicle system with the vehicle suspended below a monorail. This system went through development and sale from Vero, Inc., to Rohr Corporation and finally to Boeing. Monocab visualized a small guideway, but since vehicles were designed to be suspended, the guideway structure had to be high and required a cantilevered beam to displace the vehicles away from the vertical supports. The system later evolved into a magnetic levitation design with linear motor propulsion. Boeing developed this system further under an UMTA program that was initiated in 1964 and terminated in the mid-1980s.

Between 1968 and 1976, the Aerospace Corporation, a nonprofit federally funded research and development (R&D) center, studied the network layout, propulsion and control systems, safety, and traffic management issues and then progressed to experimental work in propulsion and control and ultimately to one-tenth-scale modeling of PRT (Irving 1978). The Aerospace system later was used as the basis for the Taxi 2000 system.

Efforts in Japan contributed to a computer-controlled vehicle system (CVS) that achieved 1-second headway and a 2,000-pound, four-passenger PRT concept. A German system developed by Messerschmitt-Bolkow-Blohm (MBB) and DEMAG called Cabintaxi supported one vehicle above and one vehicle below the guideway. The three-person vehicles ran on rubber tires and were propelled by linear induction motors. This system was licensed by Raytheon, and studies for its application in Indianapolis were conducted. Additional international development efforts were conducted in Canada, Australia, Sweden, and Great Britain (Anderson 1996).

As indicated in Table 18.1, numerous other early innovators, including General Motors, Raytheon, General Research Corporation, IBM, MITRE Corporation, Parsons Company, LTV Aerospace Corporation, Honeywell, Renault Engineering, Bendix, Ford Motor Company, and Otis Elevator Company, contributed to the development of PRT concepts. Many universities and research institutes also were engaged, including Massachusetts Institute of Technology, Johns Hopkins, Ohio State, University of Minnesota, San Diego State, Battelle Columbus Laboratories, Aerospace Corporation, Jet Propulsion Lab, and Booz-Allen Applied Research. Many of the early concepts were collected in proceedings of PRT conferences (Anderson and Romig 1974), but none found its place in a real-world commercial application until the installation of ULTra PRT at Heathrow Airport and its operational readiness trials in 2010 (Lowson 2010).

TABLE 18.1 Historical Development of Personal Rapid Transit

Year	Event	Major Players
1964	Book published: *Individualized Automated Transit in the City*, conceiving the idea of PRT.	Don Fichter
1967	Aramis Project started in Paris	MATRA
1968–1976	Book published: *Fundamentals of PRT*, documenting theoretical and system analyses of PRT	Aerospace Corporation
1972	Exposition of PRT systems, "Transport 72," held to show the benefits and features of PRT systems	Federal Department of Transportation
1972, 1973, and 1975	Three major international conferences held resulting in published proceedings	ASCE Automatic People Mover Committee
1974–1975	Morgantown GRT construction	Boeing
Middle of 1970s	Cabintaxi Project initiated in Germany	Mannesmann Demag
Early 1980s	Design of TAXI 2000 started and proposed to be implemented in Minnesota	Dr. Edward Anderson
1993–1999	Designed, developed, and tested PRT 2000	Raytheon Company
2002	Demonstration project launched for ULTra PRT system	Advanced Transport Systems
2003	Proposed PRISM program	Ford
2004	Feasibility study of PRT in Heathrow Airport	British Airports Authority
2010	Pilot operations in Heathrow Airport	Advanced Transport Systems

Source: Liu and Deng (2006).

Will PRT be the next dominating transportation mode of the century? While quite a few dominant "authority figures" were quick to dismiss the PRT idea as "inherently unsound," the idea resurges every two decades or so, and there are currently more than one-half million entries on the Internet that are directly related to PRT. With an open mind and out-of-the-box vision, some transportation professionals believe that for PRT to become a reality, it may require a revolution in the way we live and travel. That is, PRT may not be feasible if highways and private automobiles continue to be our anchor mode of transportation in the near future. On the other hand, since our society has already spent billions of dollars and built millions of miles of roads and bridges in the past century and has not complained about the expenses but proudly claims them as civilization and engineering wonders, it may just be possible to layer PRT guideways on top of the existing roadway networks and replace private automobiles with automated PRT pods.

Others who seek more progressive solutions believe that PRT is capable of adapting to existing patterns of living and working, whereas line-haul transit is only efficient in corridor developments. In a large number of metropolitan areas around the world, urban roads are already congested, and land availability and cost forbid any road expansions. With a much smaller footprint and a fraction of life-cycle costs of conventional transit such as LRT, subway, and commuter rail, PRT may be able to combine the benefits of both private automobiles and public transit by providing a no-wait, well-connected, origin-to-destination one-seat ride for most urban dwellers.

Practical engineers and rational planners understand that a single mode does not solve all the urban transportation problems; every mode has a place in the mobility spectrum. The applicability is influenced by a variety of factors, such as changing technology, economic conditions, development patterns, and social acceptance at particular times. Any entity that is contemplating the idea of PRT (or any other form of emerging technology) must undertake systematic research of the PRT technology itself and its advantages and disadvantages. A comparison must be made with other modes, such as GRT, APMs, LRT, or automobiles, as well as the costs and benefits to users and society at large.

An appropriate viability evaluation, however, should not be confined to technology alone. Market analysis, rider preferences such as mode split, given all the travel choices, and cost-benefit analysis also should be part of the viability analysis. Another important aspect to nurture a technology into fruition is the policy framework that will facilitate its implementation. Potential applications of the technology, engineering specifications, procedural implications, and marketing segmentation all should be examined.

18.4 TECHNOLOGY SPECIFICATIONS

Given the long and capricious development process of AGT technologies, it is critical to sort through the volumes of materials to extract accurate and reliable information for potential users. Development and deployment of AGT systems have been the goal of a number of investigators for over 40 years. Their design has been driven by the need to find a way to relieve urban congestion while reducing air pollution, minimizing dependence on oil, and reducing or eliminating the need for transit subsidies.

To reduce congestion, it is necessary to set aside characteristics of conventional transit to find such a solution and, without prejudice, seek to discover transit-system characteristics that would fulfill the desired needs. The new system has to be designed to minimize costs while maximizing ridership and meeting required levels of capacity, safety, reliability, security, and comfort with minimum energy use, less pollution, and integrated land use. A new system has to complement conventional transit systems and make them more effective.

Unlike traditional railroad and conventional transit, which are regulated or overseen by the Federal Railroad Administration (FRA) and the Transportation Safety Board (TSB), respectively, AGT applications do not have a clear jurisdiction in terms of safety oversight and enforcement. However, since AGTs are inherently complex systems that involve multiple interacting subsystems, new technology, and public safety, it is essential to establish minimum standards for their design, construction, operation, and maintenance.

Realizing the benefits of standardization to organizations that specify and procure APM systems, such as regulatory authorities, system suppliers, system operators, system users, and the general public, the American Society of Civil Engineers (ASCE) has taken the lead in developing "Automated People Mover Standards" (Committee of Automated People Mover Standards 2006). The ASCE standards include minimum requirements for design, construction, operation, and maintenance of APM systems, especially on the subject of the physical operating environment, system dependability, automatic train control, and audio and visual communications. The ASCE standards have no legal authority in their own right and have not been adopted by any authority that has jurisdiction over AGT applications; nevertheless, they serve as a general guideline for transportation professionals to plan, build, and manage AGT systems in the years to come.

18.4.1 Vehicles

AGT vehicles are fully automated, driverless, and either self-propelled or propelled by cables. The vehicle speed, capacity, and maximum train size are usually decided by the types of technologies selected. The typical airport APMs or DLMs have a capacity of 50 to 75 passengers depending on sitting arrangements and luggage characteristics. On the two ends of the spectrum, PRT or pod cars usually hold 3 or 4 people, whereas the airside four-car APM trains in the Hartsfield-Jackson Atlanta International Airport are capable of carrying 300 passengers. Figure 18.10 shows the range of vehicle capacity in the airport applications in the United States (Liu, Gambla, and Huang 2009).

The self-propelled APM vehicles are electrically powered by either direct current (dc) or alternating current (ac) from a power distribution subsystem, and small vehicles, such as PRT vehicle or pod cars, can be powered by an onboard battery, which may be charged along the guideway or traveling route. Cable-propelled vehicles are attached to cables and pulled along the guideway. Some cable systems have vehicles permanently attached, whereas the latest applications allow vehicles to be attached or detached depending on the operation needs.

AGT vehicles are usually equipped with thermostatically controlled ventilation and air-conditioning systems, automatically controlled passenger doors, a public address (PA) subsystem, passenger intercom devices, a preprogrammed audio and video message display unit, fire detection and suppression equipment, seats, and passenger handholds. Some APM vehicles, especially in airport applications, are designed to accommodate luggage and luggage carts.

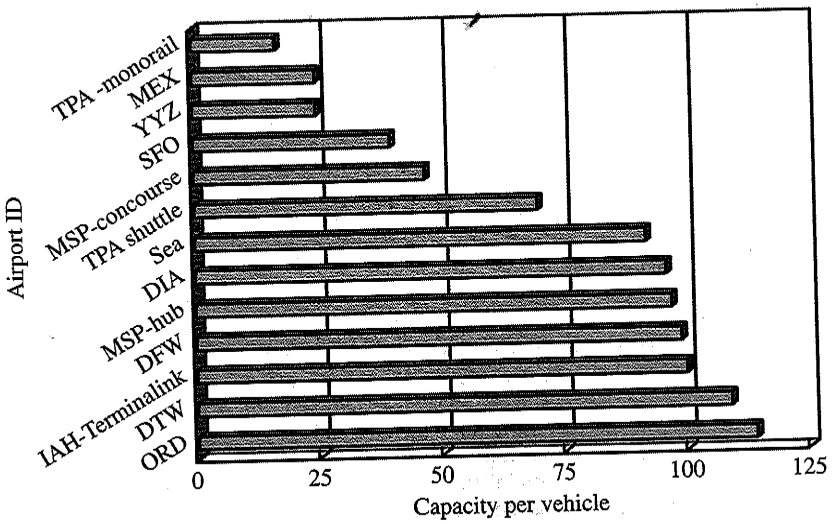


FIGURE 18.10 Vehicle capacity for airport APM applications.

AGT vehicles can be supported by rubber tires, steel wheels, air levitation, or magnetic levitation. Detailed information on each system can be found in many engineering and technical papers (Anderson 1996; Vuchic 2007). Vehicle steering and guidance mechanics vary by technology. In general, steering inputs are provided to vehicle bogies through lateral guidance wheels or similar devices that travel in continuous contact with the guideway-mounted guide beams or rails. The steering inputs cause the bogie, usually located at both ends of each vehicle, to rotate so that vehicle tires do not "scrub" as they move through horizontal curves. Both central and side guidance mechanisms have been used by different manufacturers, and each type has its own unique characteristics.

18.4.2 Guideway

The guideway is another critical element of AGT applications. It is composed of the track or other running surface, including the supporting structure, that supports, contains, and physically guides AGT vehicles to travel exclusively on the guideway. Exclusive guideways can be constructed at grade, underground, or in an elevated structure. Depending on the selected technology, the supplier, and other considerations, the guideway for AGT may be constructed of steel or reinforced concrete. Figure 18.11 shows the elevated guideway for the APM in Pearson International Airport in Toronto, Canada. The size of the guideway structure varies with span length, train loads, and any applicable seismic requirements. Span length typically ranges from 50 to 120 feet.

The individual components of an AGT guideway usually include running surfaces, guidance and/or running rails, power-distribution rails, signal rails or antennas, communications rails or antennas, and switches. For technologies that employ linear induction motors for propulsion, guideway equipment also may include either reaction rails, also called *rotors*, or the powered element of the motor, also called the *stator*.

Another important segment of guideways is called *crossovers*, and they provide the means for trains to move between guideway lanes. A crossover for most rubber-tired AGT systems is generally composed of two switches, one on each guideway lane, connected by a short length of special track

FIGURE 18.11 Double guideway for the APM system at Toronto Pearson International Airport.

work. Crossover requirements vary significantly among AGT system suppliers, and each supplier's switch and crossover requirements are discrete in that their geometric and other requirements are largely inflexible.

Many APM guideway configurations have guideway switches that allow trains to switch between parallel guideway lanes or between different routes on a system (Vuchic 2007). Different AGT technologies have different types of switches, such as rail-like, side beam replacement, and rotary switches. Steel wheel/steel AGTs use rail switches, and the Siemens VAL systems use a slot-follower switch that is similar to a traditional rail crossover switch. On the other hand, PRT vehicles typically use onboard switching with no moving parts in the guideway.

18.4.3 Propulsion and System Power

Electric power is generally required to propel vehicles and energize system equipment. Propulsion and system power typically are configured such that system operating power will be supplied by power substations spaced along the guideway. The substations house transformers, rectifiers, and the primary and secondary switchgear power-conditioning equipment. The majority of AGT applications are either self- or cable-propelled.

Self-propelled. Self-propelled AGT systems may use electric traction motors or linear induction motors (LIMs). Self-propelled APMs are electrically powered by onboard ac or dc motors using either 750 or 1,300 V dc or 480 or 600 V ac wayside rail-based power-distribution subsystems. Self-propelled AGTs are not limited in guideway length. These technologies can be used for shuttle, loop, pinched-loop, and network guideway configurations.

Cable-propelled. Cable-propelled AGTs use a steel cable or "rope" to pull vehicles along the guideway. The cable is driven from a fixed electric motor driver located along the guideway. These technologies are usually used for shorter shuttle systems, typically for distances up to 4,000 feet. Onboard equipment power is usually provided by 480-V ac wayside power. There has been recent interest among airport owners/operators in reducing power requirements for APM systems. Heightened cost awareness, the variable price of energy, and a focus on sustainability have created a strong interest in lowering the power requirements around the airport, including the APM system.

One of the examples of cable-propelled APM applications is the Toronto Pearson International APM system. The cable wheel drive in the tensioning tower weighs about 75 tons and is powered by two 1,500-kW motors. As shown in Figure 18.12, the eight-strand galvanized "rope" runs in one continuous loop into the guideway. A fixed grip assembly forms the mechanical connection between the train and the cable, which is accelerated, decelerated, and stopped by a stationary machine-drive system. Should there be a power failure, an emergency diesel kicks in to provide power for communication and for heating, ventilating, and air conditioning.

18.4.4 Communications and Control

AGT applications are marked with automated central control and communication systems, which are different from conventional guideway transit, such as commuter rail and subways. All AGT applications use command, control, and communications equipment to operate the driverless vehicles. Each AGT supplier, based on its unique requirements, provides different components to house the automatic train control (ATC) equipment. ATC functions are accomplished by automatic train protection (ATP), automatic train operation (ATO), and automatic train supervision (ATS) equipment.

ATP equipment functions to ensure absolute enforcement of safety criteria and constraints. ATO equipment performs basic operating functions within the safety constraints imposed by the ATP. ATS equipment provides for automatic system supervision by central control computers and permits manual interventions/overrides by central control operators using control interfaces.

The AGT system includes a communications network monitored and supervised by the central control facility (CCF). This network typically includes a station PA system, operation and maintenance (O&M) radio systems, emergency telephone, and closed-circuit television. The basis for many of these communications requirements is emergency egress codes such as National Fire Protection Association Code 130 (NFPA 2010). As shown in Figure 18.13, the CCF is the focal point of the control system and can vary in size from a simple room with one or two operator positions and a

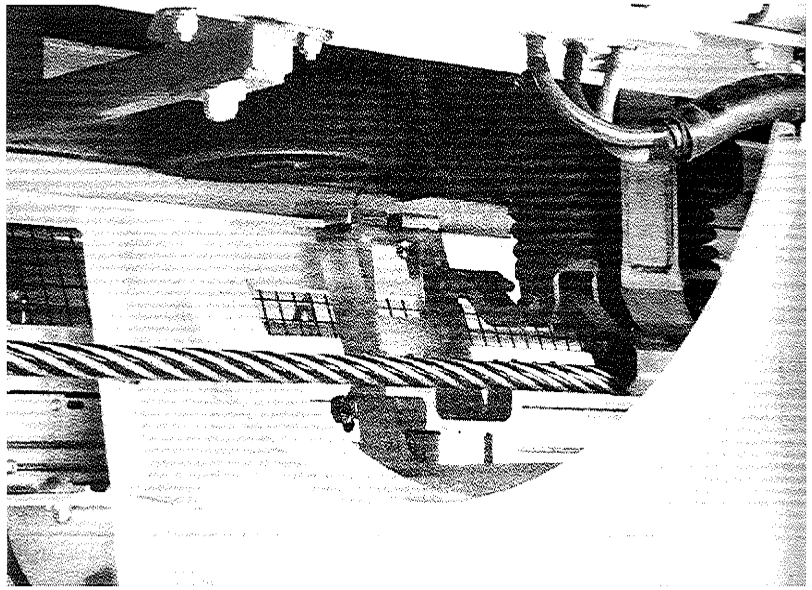


FIGURE 18.12 Cable propeller for the APM at Toronto Pearson International Airport.

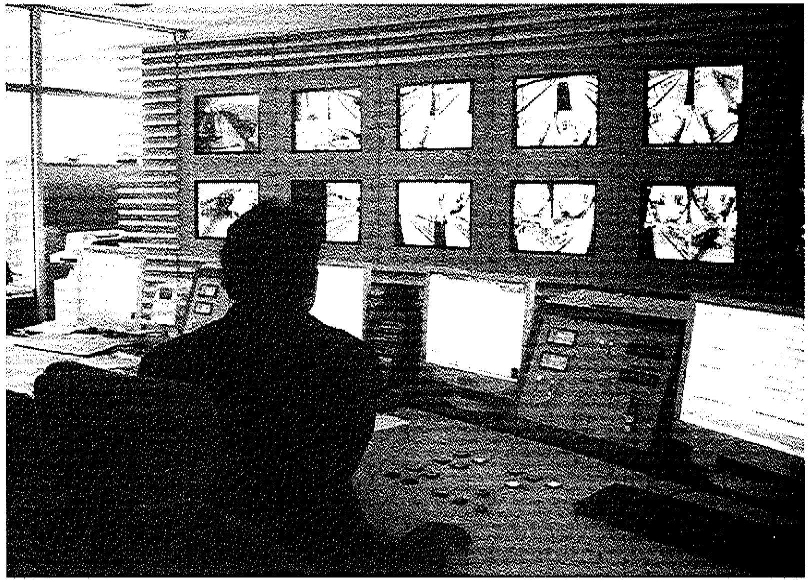


FIGURE 18.13 Control and communications facility at Toronto Pearson International Airport.

minimum of computer and CCTV monitor screens to a large room with multiple operator and supervisor positions and a large array of screens and other information devices.

18.4.5 Stations and Platforms

Similar to conventional transit stations, AGT stations are located along the guideway to provide passenger access to the vehicles. AGT stations generally are equipped with automatic platform doors and dynamic passenger information signs, in contrast to conventional transit. The AGT stations typically have station equipment rooms to house command, control, and communications equipment. In addition to the automatic train doors, the station has doors that align with a stopped train, and the two-door systems operate in tandem. The automatic station platform doors provide a barrier between the passengers and the trains operating on the guideway. These doors are integrated into a platform edge wall, as shown in Figure 18.14. The barrier wall, door sets, and passenger circulation/queuing area within the AGT station and adjacent to the AGT berthing position are commonly referred to as the *platform*. A single station can have multiple platforms. The types of platforms used depend on the type of APM configuration, physical space constraints, and any passenger-separation requirements.

An examination of the roles each platform type is needed to determine the best configuration to suit a particular application in an airport environment. The station platform doors provide protection and insulation from the guideway, noise, heat, and exposed power sources in the guideway. The interface between the station platform and the AGT guideway is defined by the platform edge wall and automated station doors. Dimensions defining the minimum width of AGT platforms and stations are developed based on analyses that take into account train lengths of the design vehicle, reasonable allowance for passenger circulation and queuing at the platform doors and escalators, passenger queuing and circulation requirements based on ridership flow assumptions, and reasonable spatial proportions and other good design practices. Stations for airport APMs typically are "on-line" with all trains stopping at all stations.

FIGURE 18.14 APM station at DFW airport. (*Courtesy of Marilyn Armardi, SkyLink.*)

Spatial, temporal, and institutional issues associated with intermodal connections are important for any transit services but are even more predominant in AGT stations. Dynamic passenger information signs typically are installed above the platform doors and/or suspended from the ceiling at the center of the station to assist passengers using the system. These dynamic signs provide information regarding train destinations, door status, and other operations.

18.4.6 Maintenance and Storage Facilities

Another key element of the AGT system is the maintenance and storage facility (MSF), which provides a location for vehicle maintenance, storage, and administrative offices. The maintenance functions include vehicle maintenance, cleaning, and washing; shipping, receiving, and storage of parts, tools, and spare equipment; fabrication of parts; and storage of spare vehicles.

The MSF typically is located away from the operating alignment in the larger AGT systems, such as airport circulation systems, DPMs, or DLMs. Vehicle testing and test track functions generally are performed on the guideway approaching the MSF when the facility is separate from the operating guideway. Simple, smaller shuttle systems often have the MSF located "under" one of the system stations or toward the end of the operating alignment. Figure 18.15 is an example of an MSF located at the end of the operating alignment at Pearson International Airport in Toronto, Canada.

FIGURE 18.15 Maintenance and storage facility at Pearson International Airport in Toronto, Canada.

18.5 AGT APPLICATIONS

The current status of AGT and its applications are critical to understanding the market need for AGT technologies. A number of feasibility studies of PRT and various stages of APM planning, design, and operating projects may serve as theoretical and practical laboratories to examine various aspects of AGT technologies and their respective successes and failures in meeting the particular travel needs of various markets. A few selected case studies are presented in this section.

18.5.1 Dallas–Fort Worth Airport APM

The Dallas–Fort Worth International Airport (DFW), located between the cities of Dallas and Fort Worth, is the world's fifth busiest airport in terms of passenger enplanements. More than 65 percent of airport usage comes from connecting passengers who usually need to travel between terminals to make their transfers. In order to accommodate the needs of growing international travel demand and to limit transfer time to 30 minutes or less for en-route travelers, DFW chose an APM as an ideal connecting mode among all terminals of DFW International Airport (Corey 2005).

At a price tag of $847 million, SkyLink, a fully automated people mover (APM) system, was constructed at the DFW International Airport and opened in the spring of 2005. As one of the largest high-speed airport train systems in the world, SkyLink features a 4.7-mile double-loop bidirectional guideway that connects six terminals, including a future one, within 8 minutes. With average travel speed in the range of 35 to 37 mph, SkyLink carries more than 3,000 passengers each hour in each direction. Figure 18.16 shows the SkyLink network layout.

18.5.2 Air Train at JFK Airport

The reason for the inclusion of an Air Train at JFK International Airport in this chapter is its unique combination of airport APM and urban metro in one AGT technology application. The John F. Kennedy (JFK) International Airport, located in New York City, is the busiest international air passenger gateway to the United States (Bureau of Transportation Statistics 2006). The Air Train at JFK International Airport is a completely automated guideway transit system that connects JFK to its adjacent cities. The 8.1-mile-long APM, which cost $1.9 billion, began construction in 1998 and eventually opened in December 2003. It has 10 stations with a 1.8-mile airport circulator loop and two extensions to urban transit systems that equal 6.3 miles.

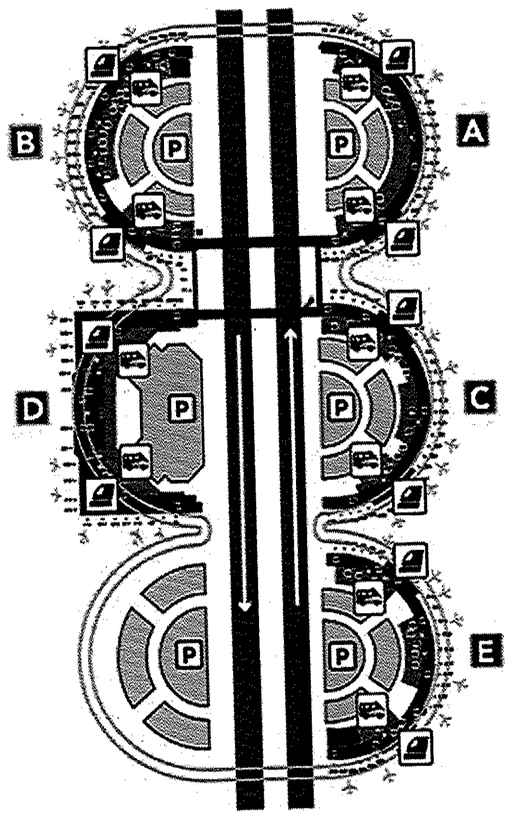


FIGURE 18.16 SkyLink at DFW International Airport. (*Source:* Dallas–Fort Worth International Airport 2008.)

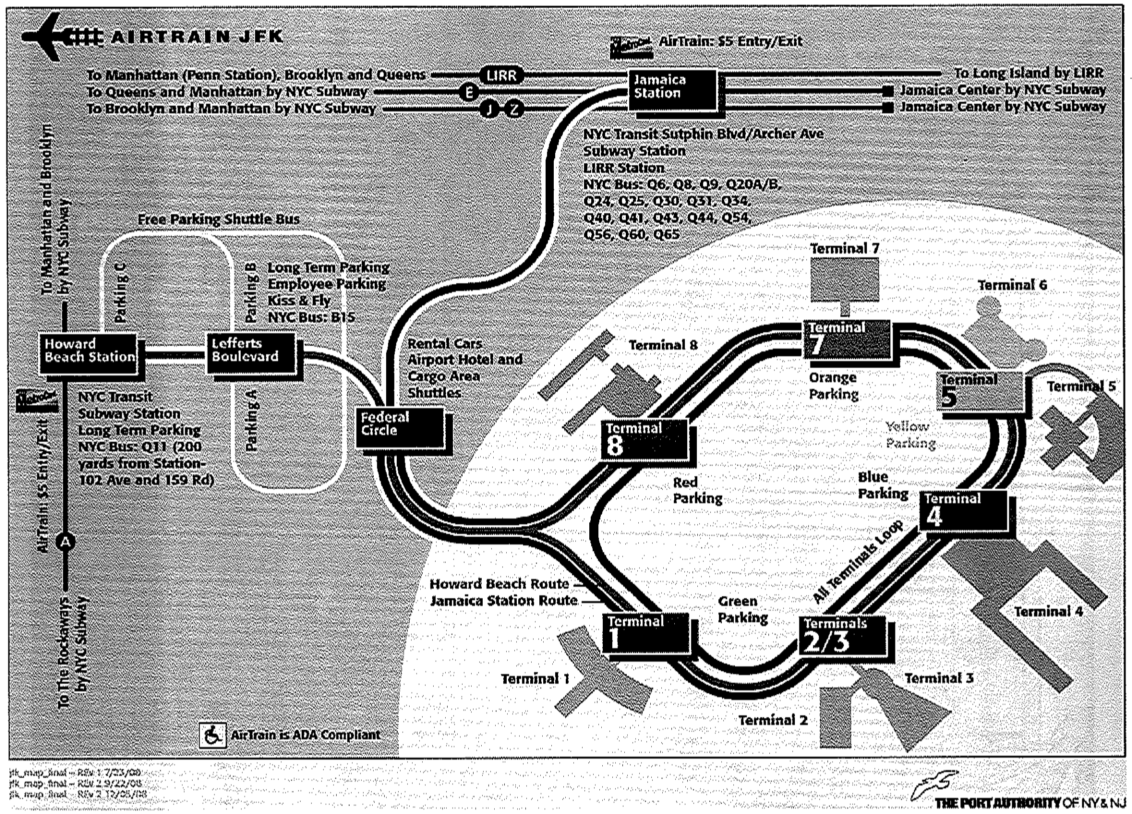


FIGURE 18.17 The Air Train at JFK International Airport. (*Source:* Port Authority of New York and New Jersey 2005.)

The Air Train uses AGT technology from Bombardier, and the capacity of the trains ranges from one to four cars with 75 to 78 passengers per car. The headway of the train is approximately 10 minutes, taking about 2 minutes between terminals. The Air Train is comprised of three main routes: All Terminals Route, Howard Beach Route, and Jamaica Station Route. As shown in Figure 18.17, the All Terminals Route is a circle route that connects all six terminal stations. The Howard Beach Route and the Jamaica Station Route connect the terminals and the regional mass-transit hubs, such as the New York urban subway and the Long Island Railroad (LIRR) stations.

18.5.3 Detroit Downtown People Mover

The Detroit DPM opened its service in 1987 with a fully automated guideway transit system operating on an elevated 2.9-mile single-track loop connecting 13 stations through the central business district of downtown Detroit. As shown in Figure 18.18, eight of the 13 DPM stations in Detroit are connected by preexisting structures, over 9 million square feet of commercial and office space, such as the Renaissance Center that houses General Motors Corporation's headquarters. The DPM enables office workers, shoppers, and visitors to travel in the downtown area with great ease. With headway of 3 or 4 minutes, the Detroit DPM takes 15 minutes to traverse the entire loop (Sullivan et al. 2005).

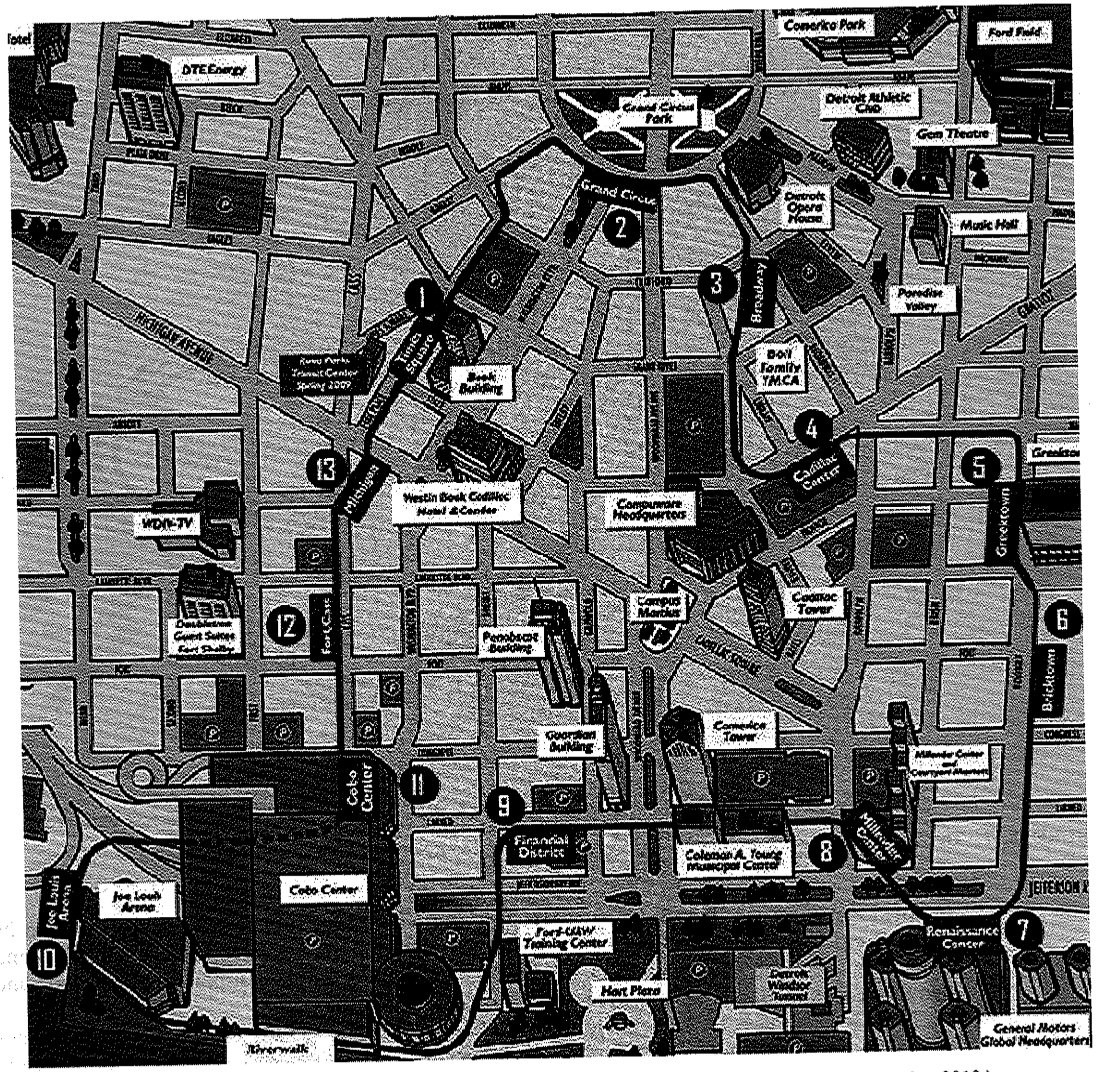


FIGURE 18.18 Detroit downtown people mover (DPM) network. (*Source:* Detroit Transportation Corporation 2010.)

18.5.4 Kuala Lumpur DLM in Malaysia

If there were a competition for AGT applications, Kuala Lumpur easily would win the crown because it has two separate AGT applications, Kelana Jaya and KL Monorail, in the same urban area. Kelana Jaya is ranked as the world's third longest fully automated DLM system at 18 miles, after the SkyTrain in Vancouver, Canada, and the Lille Metro VAL in Lille, France. Catching the expansion wave of DLMs in the world, Kelana Jaya will be extended 17 kilometers (10.6 miles) with 13 new stations by the end of 2010 (Bavani 2009).

Before 2010, there were only two-car trains operating on the Kelena Jaya Line. To increase the capacity during morning peak hours, the trains are currently running in a mixed fleet of two- and four-car train sets. The average frequency of the trains in the daytime is 4 to 7 minutes and 14 minutes after 10:00 p.m. A four-car train is able to carry up to 800 passengers at a time, with each car having a capacity of about 200 passengers. Kelana Jaya uses the newest version of Bombardier Transportation's Advanced Rapid Transit Mark II driverless train, and the maximum operating speed of such a train is about 50 mph (80 kmph) (RapidKL 2009).

In addition to the Kelang Jaya Line, the KL Monorail is the other automated transit system in the Kuala Lumpur Rail Transit System. The KL Monorail is 8.6 kilometers (5 miles) long with 11 stations. The KL Monorail had its maiden voyage in August 2003 with two parallel elevated tracks. It connects the Kuala Lumpur central transport hub with the "Golden Triangle." Two of the 11 stations run on a single track, and four of those serve as interchanges to enable passengers from the Ampang Line or the Kelana Jaya Line to transfer freely. Figure 18.19 shows both AGT trains in Kuala Lumpur.

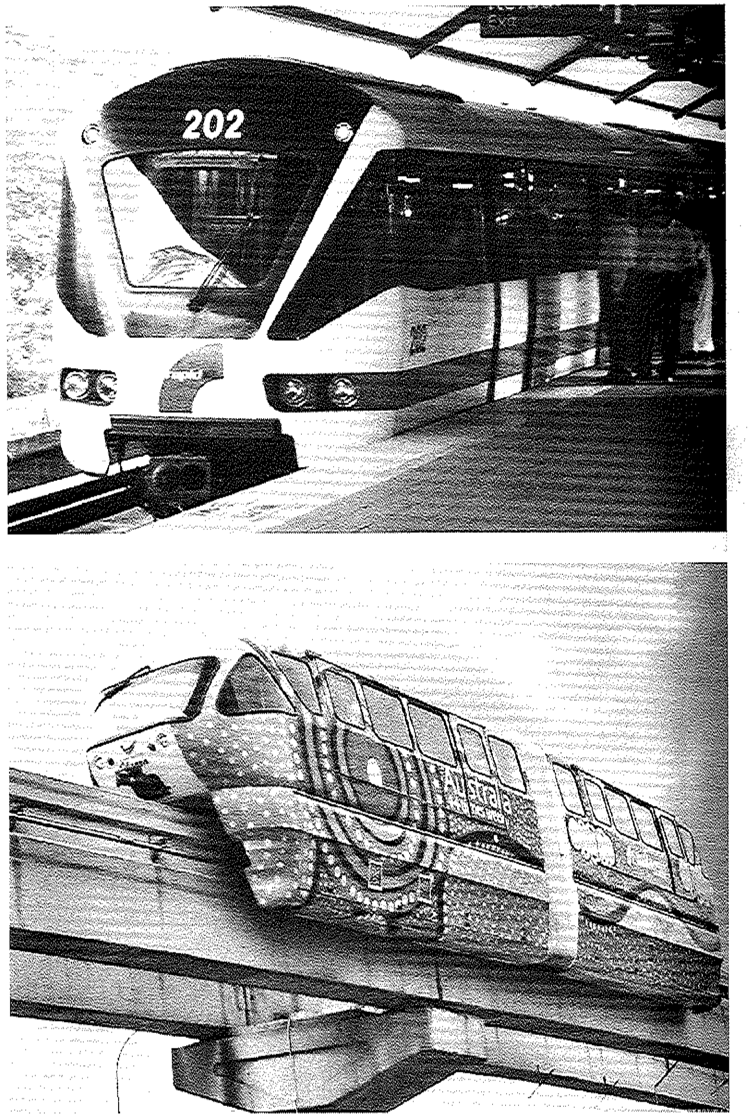


FIGURE 18.19 Automated guideway transit in Kuala Lumpur, Malaysia. (*Sources:* Yosri 2005; Teo 2009.)

18.5.5 The Las Vegas Monorail

The Las Vegas Monorail is located on the Las Vegas strip, with a total length of 3.9 miles. Running along an elevated guideway with an average height of 30 feet, the Las Vegas Monorail connects Sahara Station in the north end with MGM Grand Station in the south (Stone, Banchik, and Kimmel 2001). The system supplier is Bombardier Transportation, and the alignment is based on an existing monorail between the MGM Grand and Bally's. Opened in July 2004, the seven stations along the monorail provide easy access to several world-class resorts, hotels, and the Las Vegas Convention Center, as shown in Figure 18.20. As the nation's first fully automated urban monorail transit system, the Las Vega Monorail bears a price tag of $650 million, which was completely funded by private entities (Snyder 2005).

Besides the Las Vegas Monorail, there are three more tram or people mover applications along the Las Vegas strip alone. As shown in Figure 18.20, the Mirage–Treasure Island Tram shuttles between the two namesake hotels between 7 and 2 a.m. The Bellagio–City Center–Monte Carlo Tram connects a few more hotels in the north-south direction on the west side of the strip. The Mandalay Bay–Excalibur Tram is completely indoors, connecting the two main hotel resorts via Luxor, another large resort along the Las Vegas strip. With great variations of technology and disconnected alignment, the Las Vegas Monorail and Tram trains may serve as a showcase of AGT applications at best. It would be ideal if some coordination or integration was carried out during the development processes so that the AGT applications could form an integrated transit system with coordination and connection.

The piecemeal development of AGT in Las Vegas underlines a very important issue with AGT development: its coordination and interaction with other modes. As documented by previous studies (Liu, Pendyala, and Polzin 1997; Liu 1996), time loss and frustration associated with transfers between modes or even between vehicles within the same mode are a major impetus that discourages transit use. A true DLM can only establish its market when the transfer impetus is minimized, and travel time and reliability are superior to that of private automobiles.

18.5.6 ULTra PRT at Heathrow Airport

As the main international airport in the United Kingdom and one of the busiest in the world, London Heathrow Airport was committed to the world's first PRT to provide key connectivity for the airport in 2005. As a pilot scheme, the initial application of ULTra PRT in Heathrow was designed to connect the Terminal 5 building with a commercial parking lot to exploit the opportunities PRT may offer. The PRT service is designed to dramatically reduce the time that passengers need to move from their parked car to check-in counters.

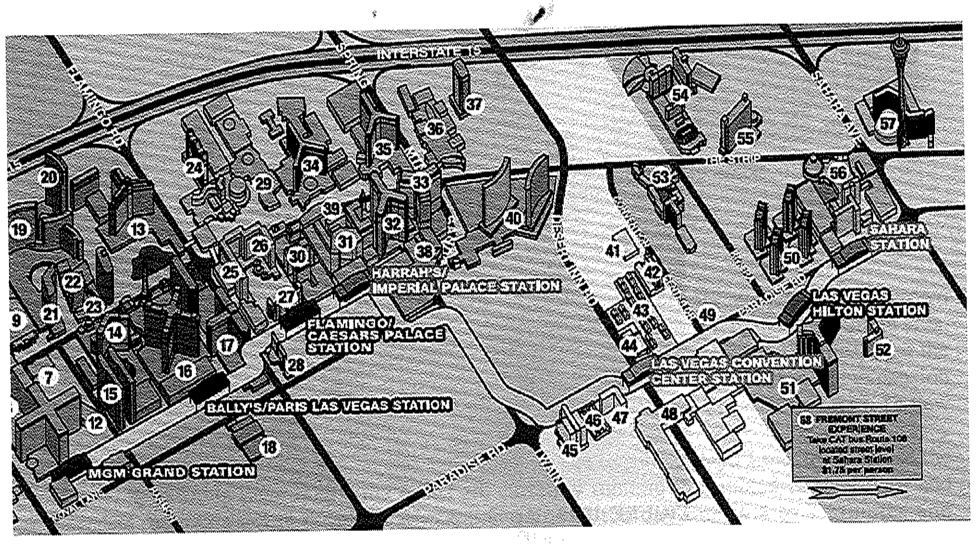
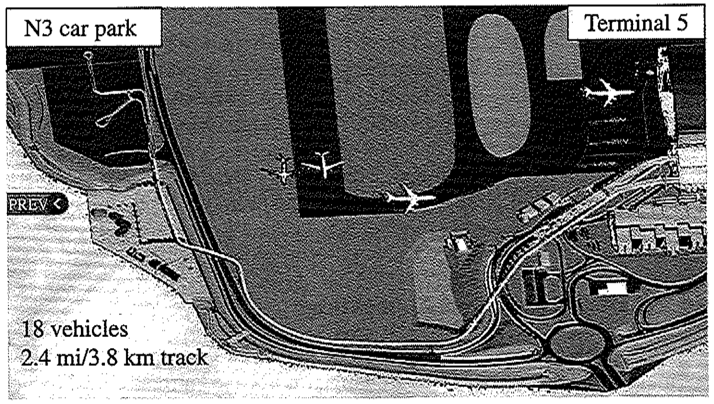


FIGURE 18.20 Monorail in Las Vegas. (*Source:* lvmonorail.com 2010.)



An early design of the 3-station Heathrow pilot system.

FIGURE 18.21 ULTRa PRT at Heathrow International Airport, London, United Kingdom. (*Source:* www.atsltd.co.uk 2010.)

Starting at a small testing scale, the initial ULTra PRT system has a 3.9-kilometer (2.4-mile) single guideway that connects three stations. The ULTRa PRT fleet is made up of 21 vehicles, and total travel time between the two terminals is about 5 minutes. The small footprint of PRT applications is well suited in this particular location because the current alignment traverses two rivers, seven roads, and green-belt land, not to mention negotiating aircraft surfaces and bridge in-ground services while conforming to the Terminal 5 architecture and appearance styles, as shown in Figure 18.21. If it proves successful, the owner of the Heathrow Airport has plans to expand the PRT application into a full network across the north side of the airport and into a newly developed Central Terminal Area (Lowson 2010).

The ULTra pods are battery powered and can hold four adults and two children including luggage, with each pod controlled by an onboard computer with sensor systems. From the perspective of energy efficiency, it is supposed to save 70 percent of the energy compared with cars and 50 percent compared with traditional buses (Rodgers 2007). After completion of construction and installation, the ULTra PRT application in Heathrow Airport has gone through a series of safety and reliability tests, including

- Basic testing at the Cardiff test track
- System integration testing
- Single-vehicle testing
- Multivehicle testing
- Operational readiness

The last testing stage, operational readiness, was conducted at the beginning of 2010. Full-scale operation is expected in the early part of summer 2010, assuming that the current test goes well.

18.6 CURRENT STATES OF AGT DEVELOPMENT

Serving as critical links in many large airports, dense downtown areas, and major activity centers, AGT applications around the world have been performing the vital function of connecting passengers to and from their origins to their destinations every day. However, since most of the AGT applications are short in length, ranging from a few hundred feet to a few miles, generally confined to the environs of airports, and owned by private operators, their importance or vitality is often ignored or taken for granted. The state of research by the AGT community does not help either. As of today, there is no substantial research or performance measures to outline concrete benefit and costs of each AGT system, not to mention their significant impact on surrounding communities.

As stated in the GAO (1980) report almost three decades ago, which is still valid today, "better justifications" and "concrete performance measures" are needed for AGT to move forward as a viable transportation mode. This section presents a brief summary of the current status of AGT development and points out the directions it may take in order to evolve and persist as a viable and sustainable transportation mode.

18.6.1 Rapid Expansion in Airport Applications

As noted by many airline passengers, larger, higher-capacity APM applications have become the normal mode to serve busy and growing airports and "airport cities," which is a recent concept consisting of a number of logically combined elements that reinforce each other not only to guide travelers easily through the airport process but also to meet the individual needs of travelers to the extent possible. APMs are no longer relegated to the peak-hour ridership of a few thousands but a normal presence for airport systems that must carry 9,000 to 10,000 passengers per hour per direction (PPHPD) during peak hours (Lindsey 2001). Atlanta Hartsfield International Airport, Washington Dulles International Airport, and Dallas–Fort Worth International Airport are all operating along the high-capacity range.

Besides the widespread airport APM applications in the United States, as shown in Figure 18.22, more airport applications are springing up in many international airports around the world. For example, Beijing Capital International Airport opened its APM system in time for the 2008 Olympic Games. Mexico City International Airport, Charles De Gaulle International Airport in Paris, and Toronto Pearson International Airport all have just opened their APM systems within the past three years.

18.6.2 Renewed Interest in PRT Technologies

The die-hard ideas for developing PRT systems may be direct offspring of the need to explore sustainable alternatives to private automobiles. Impelled by modern communication and control technologies and "*Star Trek*" quality images, PRT applications that promises to reduce congestion and air pollution and provide minimum trip time point-to-point and nonstop service at any time of the day become increasingly real and appealing. With very short or zero wait times—the vehicles would wait for people rather than requiring people to wait for vehicles—the quality of service will mollify any stubborn opposition. However, the basic requirements for safety and reliability standards can only be tested and validated when a real application is put into place. Not many entities are brave enough to make the commitment before a concrete or comfortable cost range and related ridership estimates are provided, which again will be possible only with adequate scale and real-world applications.

A quick scan of the existing literature and ongoing PRT studies reveals that the specifications of technology and assessment of costs may be relatively straightforward, but quantifying benefits associated with the implementation of a transportation project and evaluating the market conditions are complex. There are a number of analytical tools to assign a dollar value to benefits; however, some impacts, such as congestion relief, safety improvements, and air quality improvements, are often difficult to quantify financially. Other qualities, such as aesthetic appearance, may not even be quantifiable. Environmental and societal impacts are often referred to as *external* effects of transportation activities because they are not reflected directly in monetary costs and benefits of project implementation. By externalizing these factors, cost-benefit analyses often do not capture the full value of beneficial impacts.

The most difficult task so far to convince decision makers or the public of the feasibility of PRT applications is the estimation of ridership in the absence of *revealed preference* (RP) data. While many studies may use *stated preference* (SP) data before a real-world application may take place, the biases associated with SP data are well known, and the discrepancies between the two are difficult to estimate. Further complicating PRT ridership estimates is the intermodal transfer penalties associated with its initial applications. When starting from a short segment, an individual corridor, or some other type of limited scale, which is no different from the initial segments of any other transportation project, PRT may suffer from lower ridership owing to its limited network coverage and heavy intermodal penalties.

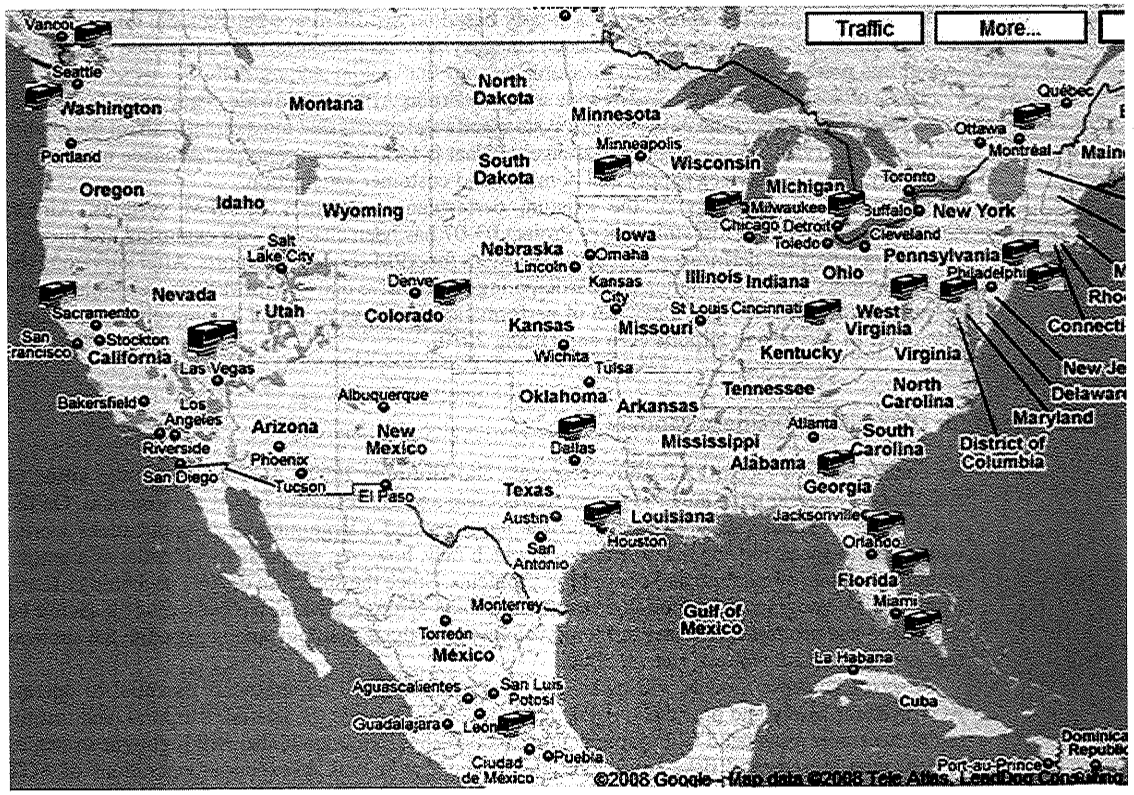


FIGURE 18.22 Widespread airport APM applications in America.

18.6.3 Evolving Performance Measures

As mentioned earlier, most of the APM systems are short in length, generally confined to the environs of airports, and owned by private operators of the various facilities. There is very limited research on APM systems, not to mention performance measures of such systems. The reason for this lack of linkage between performance measures of APM systems and demand is manifold. One of the key causes may be that the performance of APM systems is narrowly measured for existing systems. In many cases, performance measures of APM systems are specified in contract documents as a means of verifying the operator's compliance with contractual requirements.

Specified performance measures for airport systems typically are based on scheduled and actual operating data. The typical parameters generally are reflected by the following:

- Service mode availability
- Fleet availability
- Station platform door availability
- System service availability

Calculation of the first three items is simply based on the difference between the total operation periods minus the downtime period of each category. The last measure, system service availability, is the final product of the first three measures.

These availability measures are in wide usage in airport APMs worldwide. They provide the most appropriate level of accountability for the system and its elements that most directly affect the quality and level of service experienced by passengers. What is lacking in current performance measures is efficiency, balance between supply and demand, and customer satisfaction.

Given the shortcomings of the existing performance measures of APM systems, Airport Cooperative Research Program (ACRP) Project 03-07 has been charged with exploring and proposing a comprehensive performance measuring system for APM service at airports. After surveying the APM operators in North America and participating in extensive dialog with various stakeholders, the research team has developed a new set of performance measures to reflect a comprehensive evaluation of APM services in airports (Liu and Huang 2010).

18.6.4 Need for Diversified Business Models

As concluded in a recent PRT study (Carnegie and Hoffman 2007), AGT possesses the virtue of sustainability owing to its small footprint, lower cost, and lower impact on the environment. On the other hand, its small size and low-key profile have fostered a large number of applications worldwide without garnering any major headlines, which may, however, suppress its potential as a unique solution to urban circulation and congestion problems. Since the spectrum of AGT technology stems from various geographic, operational, and institutional settings, several business models should be developed and promoted to foster further development of the technology and to expedite the application processes (Liu, Nelson, and Lu 2009).

A set of business models will establish the core operational requirements essential to operate AGT systems safely and profitably. A business model can address the spatial, temporal, and institutional structures associated with implementation of AGT technology. It also will highlight strategies to deal with incremental risks and liabilities associated with new or expanded operations of AGT systems. Business models will identify potential funding sources, market-analysis procedures, and ridership shares when compared with other modes based on domestic and international experience.

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GLOSSARY

ac	alternating current
ACRP	Airport Cooperative Research Program
AGT	automated guideway transit
APM	automated people mover
ASCE	American Society of Civil Engineers
CCF	control and communications facility
CCTV	closed-circuit television
dc	direct current
DFW	Dallas–Fort Worth International Airport
DIA	Denver International Airport
DLM	driverless metros
DLT	driverless transit
DPM	downtown people mover
DTW	Detroit Metropolitan Wayne County Airport
FRA	Federal Railroad Administration
FTA	Federal Transit Administration
GAO	General Accounting Office
GRT	group rapid transit
IAH	Bush Intercontinental Airport
JFK	John F. Kennedy International Airport
kmph	kilometers per hour
LIM	linear induction motor
MEX	Mexico City International Airport
mph	miles per hour
MSP	Minneapolis–St. Paul International Airport
NFPA	National Fire Protection Association
ORD	O'Hare International Airport
PA	public address
PRT	personal rapid transit
SEA	Seattle/Tacoma International Airport (SEA-TAC Airport)
SFO	San Francisco International Airport
SP	stated preference
TPA	Tampa International Airport

TSB	Transportation Surface Board
ULTra	urban light transport
UMTA	Urban Mass Transportation Administration
YYZ	Toronto Pearson International Airport

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CHAPTER 19

RAILWAY VEHICLE ENGINEERING*

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19.1 DIESEL-ELECTRIC LOCOMOTIVES

Diesel-electric locomotives and electric locomotives are classified by wheel arrangement; letters represent the number of adjacent driving axles in a rigid truck (A for one axle, B for two axles, C for three axles, etc.). Idler axles between drivers are designated by numerals. A plus sign indicates articulated trucks or motive power units. A minus sign indicates separate nonarticulated trucks. This nomenclature is fully explained in RP-5523, issued by the Association of American Railroads (AAR). Virtually all modern locomotives are of either B-B or C-C configuration.

The high efficiency of the diesel engine is an important factor in its selection as a prime mover for traction. This efficiency at full or partial load makes it ideally suited to the variable service requirements of routine railroad operations. The diesel engine is a constant-torque machine that cannot be started under load and hence requires a variably coupled transmission arrangement. The electric transmission system allows it to make use of its full rated power output at low track speeds for starting as well as for efficient hauling of heavy trains at all speeds. Examples of the most common diesel-electric locomotive types in service are shown in Table 19.1. A typical diesel-electric locomotive is shown in Figure 19.1.

Most diesel-electric locomotives have a dc generator or rectified alternator coupled directly to the diesel engine crankshaft. The generator/alternator is electrically connected to dc series traction motors having nose suspension mountings. Many recent locomotives utilize gate turn-off inverters and ac traction motors to obtain the benefits of increased adhesion and higher tractive effort. The gear ratio for the axle-mounted bull gears to the motor pinions which they engage is determined by the locomotive speed range, which is related to the type of service. A high ratio is used for freight service where high tractive effort and low speeds are common, whereas high-speed passenger locomotives have a lower ratio.

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