MATERIAL HANDLING & LOGISTICS
U.S. ROADMAP

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Executive Summary

We live in a highly connected world that is complex and becoming increasingly so. In the midst of this complexity, all the pieces must fit and work together to accommodate continuous and sometimes mind-boggling change.

This is the environment for material handling and logistics in 2014. Material handling and logistics provide the connections that move goods through the supply chain and into consumers' hands. The impact of the industry on the U.S. economy is extremely broad, touching everything from raw materials at the point of origin to final delivery at the front door of the consumer to recycling and end-of-life disposal. One faulty connection along the way can mean consumers go without or that they pay too much for their goods.

THIS REPORT COMPILES WHAT MORE THAN 100 INDUSTRY THOUGHT LEADERS HAD TO SAY ABOUT THE FUTURE OF MATERIAL HANDLING AND LOGISTICS

Fortunately, the industry in the United States is robust and innovative. The United States has some of the lowest logistics costs of any country, accounting for 8.5% of our Gross Domestic Product.[1] Although that is a great competitive position to be in, it is no longer enough. Expectations of consumers of all types are rising rapidly, creating heavy pressure for rapid and profound change. At the material handling and logistics trade show ProMat 2013, futurist Edie Weiner talked about the speed of that change: "It is happening at an exponential, exponential rate, and I did mean to repeat myself."

Consider just one aspect of the supply chain: the delivery of goods to consumers. No longer is two-day or next-day delivery enough. The next horizon is already here—same-day and same-hour delivery. It may not be long before people specify exactly where they need goods to be delivered today, not to an address but to the temporary location of an individual. Such a system would require precise timing of delivery; otherwise, the recipient may have moved to another location. What may have sounded fantastical just five years ago now seems to be on the horizon.

This report compiles what more than 100 industry thought leaders had to say about the future of material handling and logistics. Participants at four day-long workshops included material handling and logistics end users, suppliers of equipment and software, and members of academia, government, associations and the media.

The U.S. Roadmap for Material Handling & Logistics was commissioned to identify the current challenges and necessary future capabilities of material handling and logistics. It projects out to 2025 how the industry will need to adapt its technology, practices and workforce to keep pace with the demands of change.

These public workshops also made clear that the material handling and logistics industry has a direct impact on many aspects of our economy. With more than $1.3 trillion in annual spending, the industry has a profound and direct impact on jobs, U.S. global competitiveness and our standard of living.

1. 24th Annual State of Logistics Report, "Is this the new normal?" Council of Supply Chain Management Professionals, pg. 2, 2013.

SUMMARY OF MAJOR FINDINGS

The Roadmap identifies 10 major trends in the economy, technology and society that will shape the future of the industry:

- the growth of e-commerce,
- relentless competition,
- mass personalization,
- urbanization,
- mobile and wearable computing,
- robotics and automation,
- sensors and the Internet of Things,
- Big Data and predictive analytics,
- the changing workforce, and
- sustainability.

Some of these trends, such as e-commerce and relentless competition, are well underway and moving toward maturity. Others, such as Big Data and the Internet of Things, are in the early stages of development and probably won't be mature even in 2025. Each trend, however, has the potential to have a tremendous influence on the material handling and logistics industry in the future.

From these trends, workshop participants spent considerable time developing corresponding challenges and opportunities, and then asking what capabilities the industry should develop in response. An extremely wide range of issues was addressed— from robotics to driverless trucks to workforce recruiting and training. Despite the variety, a number of important themes emerged:

People, people, people: The industry already faces a workforce challenge, both with respect to finding good workers and training them. Absent a purposeful, coordinated effort in the future, these problems will only get worse. The industry cannot continue to grow without engineers to engineer, managers to manage, and workers to work.

The Roadmap identifies a number of important capabilities to address this challenge, including coordinated efforts to promote the field, reach out to new demographic groups, and improve skills training and certification.

Collaboration: Statistics on empty truck miles and facility utilization suggest that dramatic reductions in cost are possible, if high levels of collaboration and sharing could be achieved in the industry. It was widely believed that significant levels of collaboration in the industry could lead to breakthrough reductions in the cost and environmental impact of logistics. Participants identified a number of promising areas.

Despite the significant benefits of widespread collaboration, real obstacles stand in the way. Technological obstacles related to data sharing and security are certainly not insurmountable. What might be insurmountable is the need for companies (sometimes competing companies) to trust one another enough to achieve the needed levels of asset and information sharing. There is much to do.

Sensors, data and algorithms: Imagine a world in which physical objects are able to communicate with people and information systems with low-cost sensors. Imagine a world in which nearly every fact a company needs is available instantaneously. Imagine a world in which sophisticated algorithms make low- and mid-level decisions optimally and automatically, leaving humans to perform tasks that require judgment and intuition. That world will be here by the year 2025.

The challenge for the material handling and logistics industry is to harness these technological capabilities—most of which are occurring outside the industry itself—and use them to the greatest advantage. The Roadmap makes several recommendations in this regard, including real-time optimization of distribution systems, cloud-based data from ubiquitous sensors, and sharing protocols to protect sensitive data.

New methods of distribution: The retail industry in particular is in the midst of a sea change in distribution models. Amazon started the transformation with Amazon Prime offering guaranteed “free” and fast delivery. Other retailers have followed suit out of competitive necessity. Now Amazon and others are pursuing same-day and same-hour delivery, which will put even more pressure on material handling and logistics systems for high-throughput, high-speed operations.

The Roadmap describes these initiatives and their implications for the industry, including emerging distribution models based on crowd-sourcing and delivery to mobile customers. Whether these models will become important parts of the distribution marketplace is a matter of speculation, but the material handling and logistics industry will play a vital role in determining their viability.

Introduction

Material handling and logistics are the backbone of the U.S. economy. Everything in our homes, businesses, malls and everything in between got there because of material handling and logistics.

From raw materials to finished goods, every item of physical commerce had a ride on a conveyor or lift truck or other type of material handling equipment in manufacturing plants and distribution centers. And when those plants and warehouses shipped an item, it then rode on a truck, plane, railcar or ship through a logistics system to its next destination.

When all that movement and handling is added up, it accounts for 8.5% of gross domestic product, which is at least $1.33 trillion—and the total continues to grow at roughly 4% annually. And yet, these costs as a share of GDP are among the lowest in the world.

According to the Department of Transportation, the nation's freight transportation system annually handles nearly 18 billion tons of materials and goods valued at $16 trillion.[2] That is, on average, more than 48 million tons of freight, valued at more than $46 billion, being moved every day of the year.

Critical logistics nodes include the 145 ports in this country that each handle at least 1 million short tons annually. There are also 160,000 miles in the national highway system. On the rail side, there are more than 100,000 miles of freight rail and 550 common freight rail carriers in the United States.

2. U.S. Department of Transportation, Federal Highway Administration, Office of Freight Management and Operations, "Freight Analysis Framework," pg. 9, 2012.

At various destinations in that logistics network, material handling equipment handles goods from pallet loads to intermodal containers. Material handling also figures prominently within the four walls of manufacturing and distribution facilities. There, these systems handle, store and move raw materials, parts, components and finished goods at the 300,000 manufacturing sites and 350,000 warehouses in the Unites States.

In all, 7.5 million businesses are served by material handling and logistics on a daily basis. In addition, more than 300 million consumers in this country benefit directly from the industry.

At the same time, the material handling and logistics industry is very much a silent partner in our economy. We often take it for granted when we go to the store that what we want to buy will be there. Only when there are port delays or a new smart phone is in short supply do people outside the industry hear much about what is happening behind the scenes.

IN ALL, 7.5 MILLION BUSINESSES ARE SERVED BY MATERIAL HANDLING AND LOGISTICS ON A DAILY BASIS

But that's only part of the story. The material handling and logistics industry is also critical to job creation and economic growth.

To begin, the Bureau of Labor Statistics pegs transportation and logistics as the second largest employment sector in the United States with more than 6 million people.[3] According to the Georgia Center for Innovation, the field will generate 270,000 new jobs annually through at least 2018. At the current job creation rate, that's more than 10% of all new jobs in America for the next few years.

As the World Bank noted in its 2012 report "Connecting To Compete," supply chains are critical to national competitiveness:

- "The tremendous importance of logistics performance for economic growth, diversification and poverty reduction has long been widely recognized."
- "While primarily conducted by private service providers, for private traders and owners of goods, logistics is also important for the public policies of national governments, and regional and international organizations."
- "Better overall logistics performance and trade facilitation are strongly associated with trade expansion, export diversification, attractiveness to foreign direct investment and economic growth."

3. Bureau of Labor Statistics, National Occupational Employment and Wages Estimates, May 2012. Included are more than 2.3 million truck drivers and 3.4 million material handlers.

Similar remarks were made by acting secretary of commerce Rebecca Blank to the department's Advisory Committee on Supply Chain Competitiveness. She said, "America's robust, innovative and well-run supply chains provide our businesses and workers with a competitive advantage in the global economy."

Blank added, "An area that requires our attention—of particular interest to all of us here at the Commerce Department—is how to integrate supply chain infrastructure and supply chain competitiveness into our efforts to bolster U.S. exports."

Ultimately, material handling and logistics have a direct impact on the cost of goods that everyone buys. According to the Department of Commerce,[4] a 10% reduction in transportation costs reduces the total operating costs for companies by 1%. And, we all know the power of a company's supply chain to contribute directly to lower product costs. Just think Amazon and Walmart, to name two.

A ROADMAP TO THE ROADMAP

Participants in the Roadmap workshops went through a three-step process to identify trends, resulting challenges and needed capabilities. The Roadmap itself is organized roughly according to this process.

4. Remarks by Department of Commerce Acting Secretary Rebecca Blank to the Department's Advisory Committee on Supply Chain Competitiveness, October 19, 2012.

The next chapter describes *What 2025 Will Look Like* by identifying 10 major trends affecting society, technology, the economy and the environment. These trends are in different stages of development—some are well on the way to maturity while others are just emerging. Capabilities the industry should develop in response are described in the three chapters that follow.

High-Speed, High-Value Material Handling and Logistics describes ways the material handling and logistics industry can meet the increasing demands for new logistics services in challenging environments. Capabilities are listed in five major areas: total supply chain visibility, standardization, planning and optimization, e-commerce and high-speed delivery.

Low-Cost, Low-Impact Material Handling and Logistics describes capabilities that will keep the financial and societal burden of the industry at the lowest possible levels while delivering the high-value services expected of the industry. Capabilities are in four major areas: collaboration, urban logistics, technology and automation, and sustainability.

TO ADDRESS THE CHALLENGES IN THIS ROADMAP, NEW ORGANIZATIONS AND NEW COALITIONS WILL HAVE TO BE CREATED

The final chapter addresses significant challenges in *The Workforce of Tomorrow*. This topic received significant attention at the workshops. The challenges in this area are formidable.

A CALL TO ACTION

To address the challenges in this Roadmap, new organizations will have to be created: new coalitions of companies, non-government organizations, and, in some cases, government will have to form. Other challenges will likely be addressed by companies and individuals through natural market forces. The beauty of the U.S. economy is that true individual and societal needs are met by willing providers for the right price.

What 2025 Will Look Like

"Roadmap" implies a destination—what will the U.S. material handling and logistics industry look like in the year 2025? Where are we headed? No one has a crystal ball, of course, but the future will be determined partly by current trends in society, technology and the economy. Participants in the Roadmap workshops identified several trends as critical for the future of the industry. The three chapters that follow describe specific capabilities to meet these challenges.

THE GROWTH OF E-COMMERCE

The retail landscape has been forever changed by electronic commerce, and it's clear that we are witnessing only the beginning of a profound transformation in the way Americans buy products.

Forrester Research estimates that online retail will comprise 10% of all retail sales by 2017, up from about 8% today.[5] That relatively small-sounding increase is actually a 9% compound annual growth rate (CAGR) from $231 billion in 2012 to $370 billion in 2013. The report cites two underlying causes: (1) increasing use of mobile devices, leading consumers to spend more time online; and (2) traditional retailers making greater investments in e-commerce fulfillment and omni-channel distribution systems. Which is to say, demand and supply are working together to increase the size of the market.

5. Forrester Research Online Retail Forecast 2012 To 2017 (US), as quoted in Lauren Indvik, Forrester: U.S. Online Retail Sales to Hit $370 Billion by 2017, http://mashable.com/2013/03/12/forrester-u-s-ecommerce-forecast-2017.

"As e-commerce sales rise, so will the number of Americans contributing to that total. [It is estimated that] 87.5% of U.S. Internet users ages 14 and older, or 178.5 million people, will browse or research products online this year. Of that group, 83% will make a purchase online, for a total of 148.1 million online buyers in 2011. By 2015, 170.3 million people, or 76.3% of the online population, will make a purchase on the Web."[6]

The rise of shopping on mobile devices has given rise to the term m-commerce, which one firm estimates will comprise 16% of all online retail purchases in the 2013 holiday shopping season.[7] More mobile devices lead to more time spent online, which leads to more purchases online.

IN 2012, TOTAL SPENDING IN THE LOGISTICS AND TRANSPORTATION INDUSTRY WAS $1.33 TRILLION, WHICH CONSTITUTES ABOUT 8.5% OF THE U.S. GDP

Order fulfillment for e-commerce is challenging on at least three fronts. First, delivery directly to consumers requires very fast order fulfillment times. The time to pick, pack and ship is no longer measured in days or hours but in minutes. Second, direct-to-consumer order fulfillment involves handling individual items rather than cases or pallets. Such "broken-case" order picking continues to be very labor intensive and complex. Third, sophisticated inventory policies are needed to ensure products are in stock, but without creating excessive (and expensive) safety stock levels.

By 2025 the challenge for the material handling and logistics industry is not only supporting the demands of e-commerce, but providing true, omni-channel distribution systems to support the wide variety of means through which consumers will demand their products.

RELENTLESS COMPETITION

In 2012, total spending in the logistics and transportation industry was $1.33 trillion, which constitutes about 8.5% of the U.S. GDP. Dollars of this magnitude not only attract more competitors, but also expand the nature and scope of the services provided.

An example can be found in the rise of third-party logistics (3PL) providers. As companies began to outsource logistics several decades ago, the 3PL industry responded with turnkey support, thereby freeing their customers to focus on core strengths. Since that time, the number of 3PL companies has exploded, as has the range of services they provide.

Broadly speaking, competition takes place along two dimensions—price and service offering. Aggressive cost-cutting through increasing scale, better planning and wise use of technology will continue to be an important staple in the business plans of successful companies.

But companies also compete aggressively on service. For example, the total time to deliver packages after an order is placed has become a primary service offering in

6. eMarketer, Healthy Growth for Ecommerce as Retail Continues Shift to the Web, 2011, http://www.emarketer.com/Article/Healthy-Growth-Ecommerce-Retail-Continues-Shift-Web/1008284.

7. eMarketer, Mobile Devices to Boost US Holiday Ecommerce Sales Growth, Sept 5, 2013.

many industries. The demand for shorter lead times has become an imperative for inbound logistics in support of production, with the proliferation of lean and just-in-time operations. However, this is also a competitive advantage for business-to-consumer (B2C) delivery, as the growth of Amazon Prime is proving. Amazon Prime has been called possibly "the most ingenious and effective customer loyalty program in all of e-commerce, if not retail in general."[8]

Another area of competition will be high-quality support services. For example, many companies currently offer the ability to track packages, but the resolution of these systems seems inadequate compared to what could be offered. Future tracking systems could offer complete, end-to-end visibility of shipment location, as well as an accurate prediction of delivery time. Such status updates could be offered in active or passive mode to all types of devices.

BY THE YEAR 2025, THE MATERIAL HANDLING AND LOGISTICS INDUSTRY WILL HAVE TO OFFER A WIDER SUITE OF SERVICES, WORK FASTER AND OFFER A LOWER PRICE POINT

Future systems should also be flexible enough to respond to changes in delivery location and time, without undue cost. Of course, damaged or mistreated goods (due to temperature changes, for example) will be unacceptable. One way to avoid such errors would be the deployment of appropriate sensor systems and alerts.

By the year 2025, the material handling and logistics industry will have to offer a wider suite of services, at a faster rate and at a lower price point. The many competitors in the space will ensure this happens.

MASS PERSONALIZATION

Since the earliest artisans offered items for sale, customization and price have been two important product characteristics to the consumer. As it was thousands of years ago, so it is today—but with a few twists.

Long ago, products were customized to the purchaser's requirements with craft guilds dominating the landscape in Europe. Toward the end of the 18th century, the French military made the significant breakthrough of using interchangeable parts for cannons and muskets. By the middle of the 19th century, many more products were being made from interchangeable parts including locks, pistols and agricultural machinery.

This paradigm shift caused consumers to become comfortable with buying standard products that were easier and cheaper to repair. This shift in consumer behavior, along with other factors, ushered in the Industrial Revolution in the United States, where mass production became king because it allowed complex products like automobiles to be made cheaply enough that average people could afford them. "Any customer can have a car painted any colour that he wants so long as it is black" (Henry Ford).

8. Stone B., What's in Amazon's Box? Instant Gratification, Bloomberg BusinessWeek Magazine, November 24, 2010, http://www.businessweek.com/magazine/content/10_49/b4206039292096.htm.

Other automobile manufacturers in the United States produced cars in different colors, but for a price. This general trend of standard designs competing on price and customized products being offered for a premium continued until about two decades ago, when yet another paradigm shift emerged.

This recent shift was forecasted in 1987 and has since been referred to as *mass customization*.[9] The ability to deliver products customized to each consumer's specifications at near mass production prices is the Holy Grail of retailing. Beginning 20 years ago, some producers devised ways to customize certain products within a mass production framework so they could be sold for a much lower price than traditional customization would have allowed. Carpet with customized color and stitch patterns is just one of many examples.

So mass customization is "giving customers the opportunity to have a product any time they want it, anywhere they want it, any way they want it," a mantra that resonates with consumers.[10] There is no reason to believe this trend will abate. Not only will the number of mass customized products grow, but personalized services will grow as well, including services in the logistics of delivering products—a result we call *mass personalization*.

By 2025, the material handling and logistics industry must be capable of supporting a highly diverse set of order and distribution channels in keeping with mass customized products and delivery methods. Customers will want to order with their phones, mobile devices and computers, as well as through traditional retail outlets, kiosks and perhaps as-yet-unimagined channels. Delivery modes will be just as diverse from time-definite, long-lead-time delivery to next-day delivery, same-day delivery and even same-hour delivery.

9. Stanley M. Davis, Future Perfect, Perseus Books, 1989.

10. MacCarthy B., P. Brabazon, J. Bramham, Fundamental modes of operation for mass customization, Int. J. Production Economics 85, 289–304, 2003.

URBANIZATION

The world continues to urbanize at a steady pace, driven both by rural migration to cities in the developing world and re-urbanization in the developed world. Today, more than 50% of the world's population lives in densely populated urban areas, and by 2050 the United Nations projects that 64% of the developing world and 85% of the developed world populations will live in cities. Although the rate of urbanization in the developing world is slowing, the absolute numbers of urban dwellers, especially in Asia and Africa, will grow to staggering levels.[11] In the United States, census data shows that rates of population growth beginning in 2010 in the largest U.S. cities now exceed suburban growth rates for the first time since the 1920s.

THE MOST RECENT ADVANCE IN THE REVOLUTION HAS BEEN TO DIVORCE ACCESS TO KNOWLEDGE FROM STATIONARY COMPUTING DEVICES

Urbanization creates many challenges for the supply chain systems that provide consumers with goods. While dense land use patterns concentrate demand, high land costs create location challenges for last-mile distribution facilities. Urban retailing typically involves larger numbers of smaller stores, and urban consumers may purchase smaller quantities per trip due to lower storage capacity in urban dwellings. Vehicle ownership rates are lower in urban areas, increasing demand for home delivery of goods and e-commerce. Urban areas are also often more demographically heterogeneous, creating demand for a higher variety of products.

On the positive side, many urban areas have established forms of public transportation (subways, rail) that might be used for logistics. Repurposing or better using other existing systems such as the U.S. Postal Service could address some of these challenges.[12]

By 2025, urban freight and logistics will be especially challenging. As population density continues to increase in urban areas, congestion and competition for highly utilized urban roadways will be a major concern. Some of the largest cities in the world already restrict truck traffic to non-peak times. New methods of distribution are needed to avoid such problems in major U.S. cities.

MOBILE AND WEARABLE COMPUTING

The Internet has ushered in an information revolution by separating knowledge from its physical manifestation (books) and by allowing worldwide, instantaneous access on personal computers. The most recent advance in the revolution has been to divorce access to knowledge from stationary computing devices. We have arrived at the point in history in which it is possible to acquire knowledge, communicate with others, act on decisions, and engage in commerce at any moment from any location.

11. United Nations Population Fund, State of World Population 2007: Unleashing the Potential of Urban Growth, 2007.

12. USA Today, "Amazon starts Sunday delivery with the U.S. Postal Service," Nov. 11, 2013.

Mobile computing is changing the way we live and at a pace that few could have imagined even 10 years ago. In 2006, Steve Jobs announced the iPhone and "the Internet in your pocket." Just seven years later in 2013, some 56% of American adults own and use a smart phone.[13] A survey in 2013 reported that 37% of American teens (ages 12-17) have a smart phone, up from 23% in 2011.[14] Three quarters of teens in this age group reported being "mobile Internet users" on cell phones, tablets or other mobile devices.

Use of mobile location-based services is also on the rise. Embedded global positioning system (GPS) capability in mobile devices allows users to gain useful information related to their current locations, but it also allows apps, algorithms and other users to know where they are. Users appear increasingly willing to offer this location information. For example, a Pew Research Center study reports that 30% of all social media users tag posts with their locations and that "74% of adult smart phone owners ages 18 and older say they use their phone to get directions or other information based on their current location."[15]

THE NEXT WAVE IN MOBILE COMPUTING APPEARS TO BE "WEARABLE COMPUTING"

The next wave in mobile computing appears to be "wearable computing," in which a computing device or a collection of sensors is embedded in a small, wearable accessory such as eyeglasses, a wristwatch or even fabric in clothing. Current applications are already being used by the health care research community to monitor physiological and environmental data of patients or study participants.[16] Google has introduced Google Glass, a small eyeglass-based computer that allows users to access the Internet, record and share audio or video, and interact on social media in real time and hands free. Such devices make possible a life—and workplace—of continuous digital input, sharing, interaction and recording.

By 2025, the material handling and logistics industry must be taking full advantage of mobile computing technologies. Constantly connected consumers will demand to know where their shipments are and how much longer they will have to wait for them. These technologies will also offer a tremendous opportunity for real-time control of logistics operations.

13. Pew Research Center, Smartphone Ownership — 2013 Update, June 5, 2013, http://pewinternet.org/Reports/2013/Smartphone-Ownership-2013.aspx.

14. Madden et al., Teens and Technology 2013, March 13, 2013, http://www.pewinternet.org/Reports/2013/Teens-and-Tech.aspx.

15. Zickuhr, K., Location-Based Services, Sept. 12, 2013, http://pewinternet.org/Reports/2013/Location.aspx.

16. Bai J., J. Goldsmith, B. Caffo, T. A. Glass, and C. M. Crainiceanu, Movelets: A dictionary of movement, Electronic Journal of Statistics, vol. 6, pg. 559-578, 2012.

ROBOTICS AND AUTOMATION

Advances in robotics and automation continue at breakneck speed. While the headlines are mostly filled with innovations in personal electronics and mobile computing, significant advances are also being made in technology related directly to material handling and logistics. Participants in the Roadmap workshops identified several areas that will have a major impact on the industry in 2025 including robotics, autonomous control, driverless vehicles and wearable computing.

The robotics industry is in the midst of a true revolution as capabilities increase and costs decrease. More than 160,000 robots were sold worldwide in 2012 alone. The International Federation for Robotics estimates that the global population of industrial robots was between 1.2 million and 1.5 million units.[17] Although most industrial robots are currently found in manufacturing applications, they are becoming more viable for material handling and logistics applications in the future.

An associated technology is autonomous control, in which a vehicle or other device has sufficient intelligence to sense its environment and make independent, local decisions. As the complexity of logistics systems continues to increase in the future, autonomous control and distributed intelligence offer a robust and flexible means of control.

THE PROSPECT OF DRIVERLESS TRUCKS IS A POTENTIALLY DISRUPTIVE TECHNOLOGY THAT COULD OFFER SIGNIFICANT BENEFIT TO THE LOGISTICS INDUSTRY

The prospect of driverless trucks is a potentially disruptive technology that could offer significant benefit to the logistics industry. Driverless cars already have been licensed in Nevada, Florida and California.[18] Significant social and technological obstacles remain, but driverless trucks could reduce the need for truck drivers, improve highway safety, and significantly reduce transportation costs.

By 2025, broadbased integration of several of these technologies into innovative and coordinated systems could result in revolutionary change in the industry.

SENSORS AND THE INTERNET OF THINGS

In 2009, Kevin Ashton took credit for the phrase "The Internet of Things" (IOT) as the title of a presentation made to Proctor and Gamble in 1999.[19] Ashton postulated that humans depend on physical things and value them far more than information because things are what we eat, wear and use in our daily lives. On the other hand, the Internet deals with data and information, and while information about things can help us improve systems, such data must be put into the Internet by humans who have very limited time and attention.

In 1999, Ashton saw radio frequency identification (RFID) as a mechanism by which physical things could directly communicate with the Internet. "If we had computers that knew everything there was to know about things—using data they gathered without any help from us—we would be able to track and count everything, and greatly reduce waste, loss and cost. We would know when things needed replacing, repairing or recalling, and whether they were fresh or past their best."

17. International Federation of Robotics, http://www.ifr.org/industrial-robots/statistics.

18. Wikipedia, "Google driverless car," http://en.wikipedia.org/wiki/Google_driverless_car.

19. Ashton, K., That `Internet of Things' Thing, *RFID Journal*, Jun 22, 2009, http://www.rfidjournal.com/articles/view?4986.

Since then, the proliferation of embedded sensors that can communicate with the Internet without human intervention is staggering. Consider that today GPS allows real-time tracking of cars and trucks—and people through mobile phones. Strain gauges rest on structural members of bridges that automatically broadcast critical information to alert highway engineers of potential problems. Vision systems can identify defects in high-speed production environments, so non-complying products can be automatically ejected from the stream prior to shipping. RFID tags attached to shipping containers can record important measurements like drop forces that the container experiences and a continuous recording of temperature in the container during transit.

Every year, sensor technology is creating smaller and better devices that can "talk" to the Internet without human intervention. The increasing array of functions that these sensors perform is also advancing at an incredible pace as is the accuracy they can achieve.

EVERY YEAR, SENSOR TECHNOLOGY IS CREATING SMALLER AND BETTER DEVICES THAT CAN "TALK" TO THE INTERNET WITHOUT HUMAN INTERVENTION

A recent McKinsey Quarterly report asserted: "The widespread adoption of the Internet of Things will take time, but the timeline is advancing thanks to improvements in underlying technologies. Advances in wireless networking technology and the greater standardization of communications protocols make it possible to collect data from these sensors almost anywhere at any time. Ever-smaller silicon chips for this purpose are gaining new capabilities, while costs, following the pattern of Moore's Law, are falling."[20]

By 2025, sensors that automatically communicate with the Internet without human intervention could be almost ubiquitous. Every step of the manufacturing process could have sensors communicating directly with the Internet, so operators would be warned of problems and be told precisely what to do. End-item packages, unit-load containers and transportation containers could have continuous GPS tracking—optimizing routing and delivery decisions. Containers should have sensors communicating vital information in real time, such as shock and temperature so remedial actions can be made if an unsafe condition is encountered. By 2025, much of Ashton's vision could be realized.

20. Chui, M., M. Löffler, R. Roberts, The Internet of Things, *McKinsey Quarterly*, March, 2010.

BIG DATA AND PREDICTIVE ANALYTICS

The world is awash in data, even "Big Data." The term "Big Data" refers to extraordinarily large data sets that companies and other organizations now collect and store about their operations, sales, customers and nearly any other transaction of interest. How is our business affected by hurricane activity in the Atlantic? Do sales increase on Mondays because of Monday Night Football? Do customers really tend to order orange sleeveless shirts with purple socks? Big Data is supposed to tell us.

The expanding field of data analysis is rooted in classical statistics, but advances in computing power and the availability of massive quantities of data has led to new techniques of data mining and data visualization. Data mining is the science of finding patterns and correlations among (possibly disparate) sets of data. The presence of such patterns can lead to better decisions in logistics and other operations. For example, knowing that customers tend to buy beer and salsa on Fridays during football season can lead grocers to anticipate this demand and be ready to meet it with sufficient stock. New techniques in data visualization allow decision makers to consider large quantities of data very quickly and therefore to make better decisions.

PREDICTIVE ANALYTICS IS A RELATED CONCEPT THAT USES DATA MINING AND OTHER TECHNIQUES TO PREDICT THE FUTURE

Predictive analytics is a related concept that uses data mining and other techniques to predict the future. It differs from forecasting in that the latter applies mathematical relationships directly to historical data to predict future values (demand, for example), while accounting for variation, trends and seasonality. Predictive analytics looks for correlation between past, perhaps disparate events and predicts future events based on current and emerging conditions. For example, the presence of certain terms on social media might portend a shift in demand for fashion items.

By 2025, these techniques will be much more mature, but likely they will not have been fully deployed. Furthermore, exploiting Big Data presupposes the data are available. Companies are naturally reluctant to share sensitive data that might be of benefit to other parts of the supply chain. The material handling and logistics industry must find ways to make appropriate data available to all who need it, while protecting the interests of owners of that data.

THE CHANGING WORKFORCE

Of all the topics discussed in the Roadmap workshops, one generated more passion and concern than the others—challenges in attracting, training and keeping an adequate workforce for the future.

Changing demographics in the United States suggest that the challenge will be even greater by the year 2025. So-called "baby boomers" will be retiring in droves and will be replaced by fewer workers in the next generation. To compound the problem, there are certain sectors in material handling and logistics in which the typical worker is already in his or her 50s.

Workforce skills are another significant challenge. As many as 270,000 new jobs are expected to be created annually in this field by 2018.[21] That is more than 10% of all new jobs in this country at current workforce expansion rates.

Attracting and keeping an adequate workforce will require the field to appeal to a much different workforce than it does today. Women, workers under the age of 35, people with disabilities and veterans are all primary targets to replace the current workforce. To attract these new people, the industry will need to establish a coordinated effort to position material handling and logistics jobs as rewarding careers that are personally fulfilling with many opportunities to advance.

With respect to skills, there is considerable concern for the existing and future workforce. On the one hand, there is a high rate of change in the technologies used and skills required to operate low-cost supply chains every day. On the other hand, skill sets of new employees at all levels are lacking. Beyond technology skills, other gaps include problem-solving abilities, situational response skills, abstract reasoning and even basic work ethic. These problems will have to be addressed by secondary and vocational-technical schools.

By 2025, the industry must have in place new initiatives to find, attract and retain the workers that are necessary for its success—and do so in the presence of many other industries competing for the same talent.

21. Georgia Center of Innovation for Logistics, "The Logistics of Education and Education of Logistics—Exploring the supply and demand of the Logistics Workforce," Nov. 2012.

SUSTAINABILITY

Since the financial crisis of 2009, businesses understandably have been focused on surviving the shock and getting lean and agile enough to prosper in turbulent times. Talk of sustainable systems has been overwhelmed in the national dialogue by other concerns in society, the economy and international politics.

Is sustainability dead? We don't think so.

Consider the most widely accepted definition for sustainable development, which was given by the World Commission on Environment and Development in 1987 and subsequently endorsed by the United Nations at the Earth Summit in 1992: "Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs." The underlying principle hardly seems controversial. Every generation wishes to leave the world a better place than it found it. To believe otherwise is to accept inevitable decline.

BY 2025, THE MATERIAL HANDLING AND LOGISTICS INDUSTRY SHOULD HAVE DEVELOPED STANDARD METHODS OF INCORPORATING SUSTAINABLE DEVELOPMENT INTO BUSINESS PLANS AND OPERATING STRATEGIES

A commonly accepted framework that applies this definition to business strategies for private and public organizations identifies three main considerations: economic development, environmental preservation and social development. In the context of supply chain systems, economic development means the creation of economic value for employees, customers and stakeholders. Environmental preservation addresses the environmental impact of supply chain operations such as effects on local wildlife, solid waste generation and emission of pollutants. Social development accounts for the effects of supply chain activities on human populations and societies, including positive effects such as education and negative effects such as pollution on public health.

By 2025, the material handling and logistics industry should have developed standard methods of incorporating sustainable development into business plans and operating strategies. Such methods should adhere to the goals of sustainability, while maintaining and even advancing the commercial interests of the industry.

WORTH NOTING

The Physical Internet

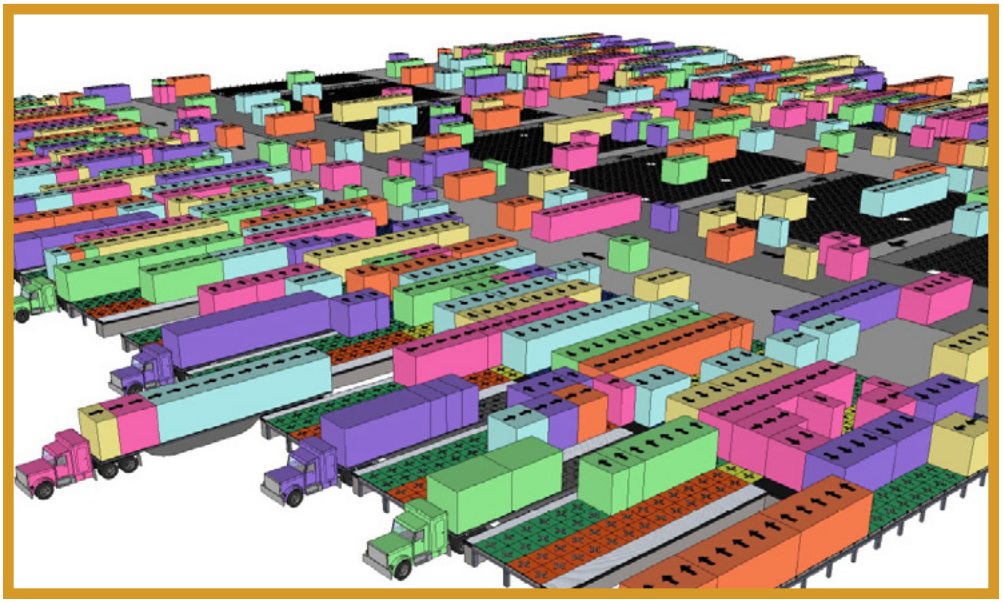
Researchers in Canada, Europe, and the United States have recently proposed a new concept in logistics that addresses many of the trends above. The *Physical Internet* is an ambitious, comprehensive vision that addresses a wide variety of problems discussed throughout this Roadmap. These include poor utilization of transportation, wasted packaging materials, poor working conditions for truckers and other logistics workers, inefficient logistics facilities, difficult urban logistics, and other problems.

THE PHYSICAL INTERNET IS AN AMBITIOUS, COMPREHENSIVE VISION THAT ADDRESSES A VARIETY OF PROBLEMS DISCUSSED IN THIS ROADMAP

The potential implications of an implemented Physical Internet are—to put it mildly—significant. A recent NSF-supported industry-academia collaborative study recently concluded that if 25% of the U.S. supply chain would adopt the Physical Internet, it would result in $100B more profit annually, 30% less greenhouse gas emission, 75% less trucker turnover, and lower prices for consumers.[22]

Similarly, a France-Canada-Switzerland PREDIT-sponsored study has shown, through a simulation experiment based on detailed flow data from major European retailers Carrefour and Casino and their top 100 suppliers, that evolving to Physical Internet enabled interconnected logistics of fast-moving consumer goods has the potential to reduce the overall logistics costs by 30% and induced greenhouse gas emissions by 60%.[23]

The Physical Internet exploits the Digital Internet as a metaphor for improving the economic, environmental and societal efficiency and sustainability of the way



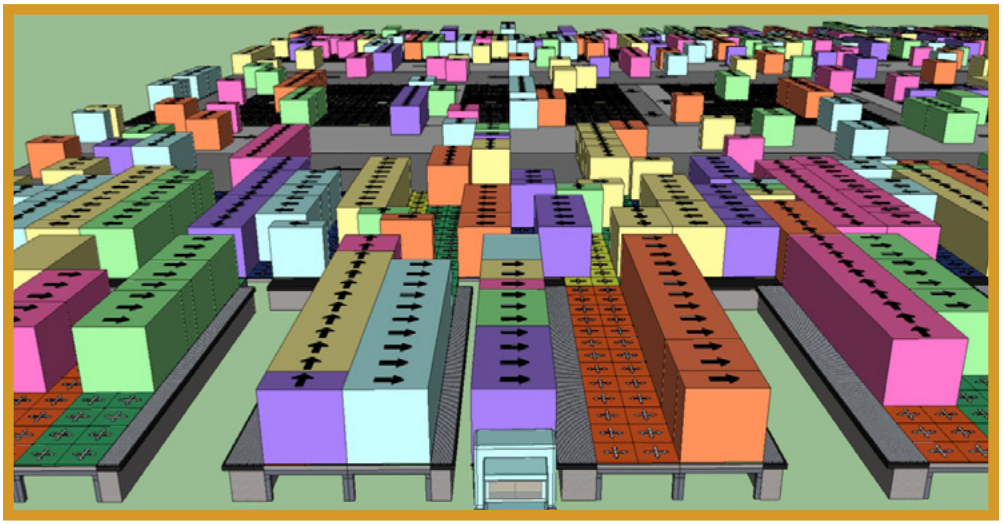
22. Meller, R., Ellis, K., Loftis, B., "From Horizontal Collaboration to the Physical Internet: Quantifying the Effects on Sustainability and Profits When Shifting to Interconnected Logistics Systems," http://faculty.ineg.uark.edu/rmeller/web/CELDi-PI/Final%20Report%20for%20Phase%20I.pdf.

23. Ballot E., B. Montreuil, R. Glardon, R. Sarraj, S. Pan, D. Hakimi, O. Gobet and M. Thémans, Simulation de l'Internet Physique: contribution à la mesure des enjeux et à sa definition, PREDIT Report, Paris, France, 200 p., 2012 (in French).

physical objects are moved, stored, realized, supplied and used all across the world. Conceptually, the Physical Internet (PI, or π) is an open global logistics system founded on principles of physical, digital and operational interconnectivity through worldwide, standardized encapsulation, interfaces and protocols. The word "open" implies that no individual owns or controls the entire system, and that anyone may use it, so long as appropriate standards are adhered to, in the same way that anyone may use the digital internet as long as digital protocols are respected.

Key properties include:

- Physical objects encapsulated in physical packets (called π-containers) designed for efficient logistics.
- Seamless interfaces across π-containers, facilities and systems. The intent is for load breaking, transhipment, pooling and modal transfer to become negligible aspects of time and costs.
- Material handling systems designed to deal exclusively with smart, modular, standardized π-containers.
- Standardization leading to a high degree of automation, with associated benefits in throughput capacity, storage density, and reduced product damage.
- Containers equipped with smart tags and unique identification, enabling universal tracking and communication with π-systems. Because the PI would interact with containers and not the products they contain, π-containers would interact with smart-tag equipped products. In this sense, the PI is in harmony with the Internet of Things, which envisions physical objects communicating over the digital internet.



High-Speed, High-Value Material Handling and Logistics

PARTICIPANTS IN THE ROADMAP WORKSHOPS WERE UNIFIED IN THEIR BELIEF THAT THE FUTURE OF THE INDUSTRY WILL DEMAND MORE VALUE AT A HIGHER SPEED

Changes in the modern economy suggest that in the year 2025, material handling and logistics will have an even greater role in the economy and society than it does today. In fact, logistics has already become the focal point of some of the most exciting developments in our modern economy.

Participants in the Roadmap workshops were unified in their belief that the future of the industry will demand more value at a higher speed. By "more value" we mean a greater focus on the customer and his or her needs—delivery at exactly the time desired, at exactly the right place, and in perfect condition, along with associated information about the delivery. By "higher speed" we mean the ever-increasing expectations that deliveries be made more quickly. As we describe here, many of these demands are being made today. By 2025, they will be the standard for material handling and logistics services.

Following are capabilities participants felt should be in place by 2025 to provide the high-value, high-speed logistics required of the industry. Capabilities are arranged in categories: total supply chain visibility, standardization, planning and optimization, e-commerce, and high-speed delivery.

TOTAL SUPPLY CHAIN VISIBILITY

Although systems already exist for customers to track shipments (FedEx, UPS, etc.), the level of detail demanded in the future will be much greater. For example, consumers can already know that a shipment was last located in a transit facility in Phoenix, but not that the shipment is tied up in traffic in Dallas or that it was placed on an earlier flight in Chicago. For commercial shipments between companies, even more precise information will be needed.

As discussed in this Roadmap, precise location services could facilitate new modes of delivery to consumers, including delivery directly to an individual rather than to an address. In such settings, consumers would want to know the precise location of delivery drivers, in addition to drivers needing to know the location of the customer.

BY 2025, ALL TRANSPORTATION ASSETS SHOULD BE TRACKABLE BY GPS

For companies in the supply chain, visibility is about more than knowing the location of an item. Available data should include current and historical environmental conditions such as temperature, humidity and exposure to vibration. Other data could also be collected depending on the application.

- By 2025, all shipments should be trackable in real time from the instant of order to the instant of delivery, in transit and in facilities, at the level of individual items and independent of carrier and transportation mode.

Capability: Deployment of GPS capabilities across transportation assets

Essential to accomplishing universal, real-time tracking is the ability to know the precise location of transportation and other material handling assets. Although global positioning system (GPS) technology is currently available, its deployment is still not universal across transportation assets.

- By 2025, all transportation assets should be trackable by GPS.

Another need is real-time locator systems (RTLS), which track and communicate locations of items to tracking systems within a warehouse, for example. Such systems are in their infancy in 2014; by 2025, they should be widely used.

- By 2025, real-time locator systems should be integrated into total supply chain visibility systems for access by supply chain partners and consumers.

Capability: Development of arrival time estimation methods

Although knowing where a shipment is located is important, ultimately customers want to know when a shipment will arrive. Needed are techniques to estimate remaining time for delivery. Such methods should account for distance, road conditions, traffic and ultimately should be able to predict time of arrival within 1% of remaining time. By that standard, the arrival time of a shipment with 24 hours remaining could be predicted

within about 15 minutes. Arrival time for a shipment four hours away could be predicted within 2.5 minutes.

- By 2025, arrival time estimation methods should reliably be within 1% of remaining delivery time.

Capability: Integration of tracking capabilities across carriers and providers

The very nature of supply chains means tracking information must come from multiple service providers. Coordinating this information will require both technological advances and, more importantly, organizational structures to ensure that the interests of all parties are protected and that validation standards are followed.

- By 2025, new protocols should be in place to track individual items throughout their lifecycle, recognizing that individual items might be transformed into other products or shipping units and back again as they make their way along the supply chain.

BY 2025, NEW PROTOCOLS SHOULD BE IN PLACE TO TRACK INDIVIDUAL ITEMS FROM THROUGHOUT THEIR LIFECYCLE

STANDARDIZATION

National and international standards provide a common language not just for physical products and equipment. They are increasingly important for describing processes, procedures, skills and metrics. Roadmap participants identified a variety of capabilities that must be established through the development, promotion and adoption of standards to enable safe, efficient, interoperable hardware and software systems.

Capability: Standardized containerization at levels smaller than current intermodal freight containers

The intermodal freight container has enabled a high rate of growth in international trade since its development in the 1950s and its subsequent widespread adoption. Global-standard, smart, modular, designed-for-logistics containers (replacing current

cartons, boxes and pallets) are needed that can accommodate raw materials and finished goods. These include unit-load, carton and transportation containers. These containers should be reusable and reconfigurable, providing the ability to take them apart and combine components to support a variety of sizes and shapes while supporting efficient automated handling.

- By 2025, major intermodal hubs throughout the United States should have the ability to handle standardized containers at the unit-load and carton level, plus load/unload integration with freight containers.

Capability: Cloud-based visibility and traceability of order, item and resource status

BY 2025, UNIVERSALLY ACCEPTED STANDARD DATA FORMATS FOR ALL TYPES OF SENSORS SHOULD BE ESTABLISHED

The lack of standards for interoperability of the various applications used by supply chain partners causes inefficiencies within and across supply chains. Standardization to support collaboration is needed to provide plug-and-play capability between trade partners. End customers and consumers are increasingly driven by visibility-based decisions that reduce variability and time to deliver.

Great strides have been made to develop transaction standards such as those in electronic data interchange (EDI), but this capability is only in its infancy compared to the standardized interoperability that will be required going forward. Standardized modular interfaces between software systems should support collaboration throughout increasingly virtual organizations. Virtual product models should be easily accessible and modified in the cloud by all pertinent players within a supply chain.

As corporate data systems shift from local physical processing and storage to cloud-based systems, it becomes far easier to develop standardized interfaces between systems of trading partners. Highly customized or in-house developed systems are becoming less common. Instead, systems that provide modular, standardized interfaces to provide for interoperability with trading partners will be more common.

- By 2025, most applications accessed by logistics and supply chain professionals should be cloud based and standards compliant.

SENSORS AND THE INTERNET OF THINGS

Advances in sensor technology continue, making at least part of the Internet of Things all but inevitable by 2025. To fully realize the vision, sensors must be made smaller and more powerful, allowing them to broadcast farther and in difficult environments such as transportation containers and packages.

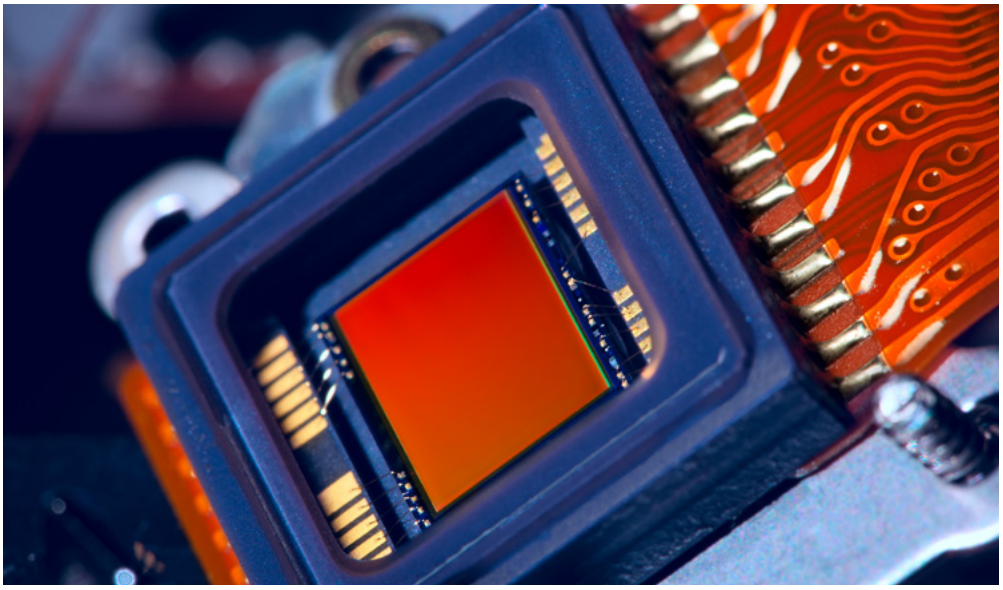
Sensors at this scale will create a torrent of raw data that must be converted into useful information. The data will be fully useful only if there are standard, universally defined formats for sensor output. Data from sensors as well as data and information from software packages must be exchanged using common protocols, and not common software platforms, and that data must be shared securely.

THE VISION FOR 2025 INCLUDES REAL-TIME, AUTOMATIC CONTROL OF MANY PEDESTRIAN SUPPLY CHAIN DECISIONS

Capability: Standardized ways of handling data from sensors

A common complaint in the material handling and logistics industry is the need to work with data in different formats. Lack of data format standards requires post-processing for analysis or comparison with other data, and this sometimes requires human intervention. The vision for 2025 includes real-time, automatic control of many pedestrian supply chain decisions (i.e., "automating the mundane"), which cannot happen without real-time data in standard formats from participating sensors.

- By 2025, universally accepted standard data formats for all types of sensors should be established.



Standardized data formats are only part of the solution. Layers of orchestration and event-driven rules engines that automatically execute certain responses when conditions have been met will still be needed.

- By 2025, software should be developed to execute automated, event-driven decision making based on input from a variety of sensor systems.

Capability: Exchange of data using standard protocols

A key to the future for the material handling and logistics industry is providing small companies as well as large ones access to the real-time data that a world with ubiquitous sensors produces. This implies that raw data from sensors as well as data and information from software packages must be exchanged using protocols, not with a common software platform that every company must purchase if they are to receive the data.

BY 2025, MOST SUPPLY CHAIN DATA SHOULD BE OPENLY AVAILABLE FOR USE

- By 2025, exchange point and protocol standards for data and information should be established. Most of the supply chain information generated should be available for all businesses at these points.

Capability: Secure data sharing across the entire supply chain

While the technical challenge of ubiquitous sensors is certainly achievable before 2025, implementation will be much more complex and difficult because it touches so many aspects of business, including competitive advantage and legal issues.

The data produced by sensors and exported from software must be shared universally to enable the real-time decision making that will satisfy customer demands and support the Internet of Things. As long as data are considered proprietary, this kind of sharing cannot happen. Participants in the workshops acknowledged that "such capabilities will require agreements on data sharing and security, in addition to new protocols and standards." They also acknowledged that it is easy to discuss the need for sharing data, but quite another thing do so in a highly competitive marketplace.

- By 2025, most supply chain data should be openly available for use. This might involve having shipments identified anonymously for the public (e.g., size, weight and destination) with a code known only by the shipper and the customer.

Capability: Real-time data

To facilitate the type of service envisioned for 2025, much of the shared data and information from sensors and software must be delivered to the Internet in real time. Sensors on physical objects and software that export information needed by others must have a "running conversation" with the Internet. This data and

information must be stored in a cloud or a new, equivalent place that is accessible to everyone—in real time. Data in such a system will have to have an "expiration date" due to the volume.

- By 2025, appropriate data from supply chain sensors should be available in the cloud or with mobile-to-mobile systems for use by appropriate parties.

Capability: Robust security of data sharing systems

Widespread sharing of data from sensors and other sources brings with it the danger of infiltration and cyber attack. As logistics information systems continue to develop, security must keep pace with the technology.

- By 2025, robust systems should exist to ensure the security of sensors and their related supply chain data systems.

PLANNING AND OPTIMIZATION

In the context of material handling and logistics, data is valuable only to the extent that it is used to make better decisions. Troves of data from a future proliferation of sensors will give the industry an opportunity to plan and execute at new levels of efficiency and improved service—if the necessary planning and optimization tools are developed.

Participants in the Roadmap workshops generally felt the current state of planning and optimization tools in the research community exceeds by far what is being used in practice. In other words, deployment and implementation of these capabilities is itself a significant challenge.

But new capabilities will be required. The output of data mining and predictive analytics models should make possible new levels of execution that could meet or be ready to meet demand even before it is realized. New methods of data visualization can present vast amounts of data quickly, either to make real-time decisions or simply to "get a feel for" an operational situation. As confidence in algorithms increases, many routine and even complex decisions could be automated, leaving humans to add value in matters of intuition, strategy and judgment.

Capability: Supply chain state assessment tools

Analysis, planning and execution of supply chains must begin with an accurate assessment of the current state. Standardized ways of assessment are needed similar to standard financial statements that record the financial health of a corporation.

BY 2025, STANDARDIZED TOOLS FOR ASSESSING THE STATE OF A SUPPLY CHAIN SHOULD BE AVAILABLE AND COMMONLY USED

One participant in the workshops put it this way: "It seems to me that many supply chain executives have no way of knowing, 'How am I doing?'"

- By 2025, standardized tools for assessing the state of a supply chain should be available and commonly used. Included in such tools might be standardized graphics to display geographical aspects of the supply chain.

Capability: Widespread availability of planning and optimization tools

The state-of-the-art software for supply chain network design and inventory optimization is already very high, and yet many small- and medium-sized businesses are not making use of it. In some cases, the challenge is one of education—companies, particularly small- and medium-sized ones, are unaware of how capable supply chain planning execution systems really are.

In other cases, the obstacle is cost. For example, supply chain design and simulation software packages are still more or less boutique products that command high prices. One Roadmap workshop participant likened what is needed to what happened to payroll and accounting software decades ago. Having previously been a specialized product at a very high price, accounting software eventually reached commercial off-the-shelf status and is now available for less than $100. However, it is doubtful that specialized supply chain software could reach such prices, simply because there is insufficient economy of scale.

- By 2025, supply chain network planning, inventory optimization and warehouse optimization tools should be standard fare and used by nearly all firms having supply chain and logistics interests. Firms not using these tools directly should be making use of consultants and other service providers who do so on their behalf.

Capability: Real-time optimization to support dynamic decision making

A less developed area of optimization is real-time decision support, in which decisions are needed not within days and hours, but within minutes and seconds. The torrent of data coming from ubiquitous sensors and data systems will make possible instantaneous re-routing of trucks, re-configuring of manufacturing lines, and re-planning of warehouse operations—if sufficient real-time optimization capabilities are available. Some capabilities exist today within supply chain and manufacturing execution systems, but much more will be needed.

- By 2025, optimization algorithms for dynamic control of logistics systems should be developed and widely used.

REDUCED DEMAND UNCERTAINTY WOULD ALSO BE USED BY MANUFACTURING AND INVENTORY PLANNING SYSTEMS TO REDUCE INVENTORY LEVELS

An extension of real-time optimization is automated decision making. Participants in the workshops believed that algorithms are or will eventually become capable of making many decisions that currently occupy the time of workers, engineers and managers. For example, in a retail cross-docking operation, late truck arrivals require supervisors to re-plan internal operations and reschedule trucks to doors. Optimal responses to such circumstances could be encoded in algorithms that would execute without management intervention or perhaps with only a cursory approval.

- By 2025, low- and mid-level decision making by supply chain execution systems should be pervasive in the material handling and logistics industry.

Capability: Models to support anticipatory logistics

Building planning and optimization models around uncertain forecast data has been common practice for decades. However, as predictive power improves with analytics in the future, decision making at a much more refined level will be possible. For example, reduced uncertainty about demand for a particular retail or food product on a certain day could lead to very tightly controlled logistics systems that deliver goods just before they are consumed. Reduced demand uncertainty would also be used by manufacturing and inventory planning systems to reduce inventory levels throughout the supply chain.

- By 2025, new planning and optimization methods should be available to exploit predictive analytics in data-rich environments.

E-COMMERCE

As e-commerce becomes an even greater part of the U.S. economy, the material handling and logistics industry will have to extend existing capabilities and develop new ones to support it.

E-commerce operations are challenging for at least three reasons. First, because shipments are directly to the consumer, special care must be taken with respect to packaging and presentation. In the distribution center, this can mean extra processing in packing and even a need for special operations such as gift wrapping.

Second, e-commerce operations typically involve a very high number of stock keeping units (SKUs), which must be picked as individual items and not as cartons or pallets. So-called "broken-case order picking" operations are typically very complex and labor intensive.

Third, speed of delivery is critical. The transportation component of order fulfillment has been well established for decades by providers such as UPS and FedEx. Rapid order fulfillment inside the distribution center is the second, less-developed piece.

Dramatically reducing order fulfillment times

The increasing SKUs problem will be exacerbated as more and more customers demand customized and personalized products. Customers also are demanding shorter order lead times—the time between placing their orders and receiving the goods. These two trends suggest dramatic changes in the handling of work-in-process and finished goods.

At a conceptual level, this challenge is rooted in the fact that personalization points toward more make-to-order items while short cycle times toward expanded use of make-to-stock fulfillment. As the number of SKUs increases to satisfy the increasing demand for customized products, the challenge is to define the appropriate mix of production.

New hardware and software systems are needed to reduce the cycle time associated with putting finished goods into storage, picking and packing, and loading transportation containers.

Capability: Systems to support rapid order processing times in the DC

Amazon has made famous the question, "Want it tomorrow? Order by such and such a time." Implicit in that promise is the ability to process an order and get it to the shipping dock before the last truck leaves for overnight delivery. These cut-off times will become competitive weapons as the e-commerce industry matures.

AS COMPETITION FOR LATE CUT-OFF TIMES INCREASES THE PRESSURE ON INTERNAL DC OPERATIONS, NEW MATERIAL HANDLING SYSTEMS AND OPERATIONAL STRATEGIES WILL BE REQUIRED

As competition for late cut-off times increases the pressure on internal DC operations, new material handling systems and operational strategies will be required. Even in the best operations today, orders can spend hours in a "virtual queue" waiting to be released to order pickers for processing. Methods to reduce these times exist, but are in their infancy and are not well developed. In particular, there is a need to organize picking operations more effectively and then to execute rapid accumulation of items into orders.

- By 2025, typical order-to-ship processing times in e-commerce distribution centers should be sufficient to support same-day delivery of in-stock items.

Profile

DRONE DELIVERY

In November 2013, Jeff Bezos announced during the *60 Minutes* news program the existence of an experimental distribution project called Amazon Prime Air. It proposes using small, autonomous quad-copters to deliver packages weighing less than 5 pounds directly to the address of customers. Significant regulatory and social obstacles must be addressed, but this initiative is just one illustration of the potential impact of new technology on the material handling and logistics industry.

Capability: Software to support hybrid storage and production systems

A different aspect of this challenge will be integrating ordinary pick-pack-and-ship operations with customized production in a mass production line with small batch handling. Although the details of each implementation will be different, moving small batches and even "batches of one" could become the norm.

A fully integrated system will be required to coordinate a large number of orders that contain customized line items. This real-time, dynamic system must continuously allocate stored items, while scheduling production for the required made-to-order items (as well as for make-to-stock replenishment).

- By 2025, systems capable of performing these tasks for hundreds of SKUs should be available and implemented in relevant order fulfillment and production facilities.

Supporting omni-channel distribution

A distribution channel is the "path" a product takes from manufacturer to distributor to customer. Traditionally, companies having multiple distribution channels (in-store and catalog sales, for example) established separate infrastructures to support each channel. For example, large retailers had separate distribution centers for catalog fulfillment and for retail store replenishment. The advantage of this approach is to

allow internal processes in each facility to be more focused and easier to control. The disadvantages are obvious: redundant infrastructure, excessive inventory and high overhead—all resulting in high costs.

The modern approach is to design facilities and processes that support multiple channels of distribution so that, for example, store replenishment and e-commerce fulfillment is handled within the same facility. Marrying disparate operations is much easier said than done.

Capability: Distribution center designs to support omni-channel operations

Accepted design concepts are needed for multi-channel distribution operations. Omni-channel distribution facilities should be able to accommodate store replenishment, e-commerce fulfillment, returns processing, light assembly or manufacturing for product customization, and even will-call operations.

- By 2025, omni-channel distribution centers that support e-commerce and other operations should be well developed and increasingly common.

BY 2025, WILLING CONSUMERS IN THE UNITED STATES SHOULD HAVE A DATA FILE WITH CUSTOMIZED INFORMATION LOCATED IN A CENTRAL REPOSITORY

Managing personalized information for individual consumers

Some of the information that customers use to personalize products does not change over time, such as clothing size. Other information does change, such as color preference for a particular item. In any event, and with privacy considerations aside, it is beneficial to both customers and businesses for data on customer preferences to be securely stored in a common repository. Consumers avoid entering data every time they make a purchase, and businesses can tailor the purchase experience to the customer. A critical component of this challenge is striking the proper balance between privacy, security, access and convenience—for the retailer and for the customer.

Capability: Central repositories with consumer information

Rather than the current practice of each business collecting data on each customer, a central repository or a series of seamlessly linked repositories should be maintained and made available to approved providers of goods and services. Customers should be able to update their profile on demand, and the data should be accessible in real time by businesses so it can be used during online transactions. Such a system might be modeled after college application data repositories, where applicants upload standard personal data and other information. Approved educational institutions then have access to the data upon receiving authorization from the applicant.

- By 2025, willing consumers in the United States should have a data file with customized information located in a central repository. E-commerce retailers meeting security requirements should have access to this information.

HIGH-SPEED DELIVERY

At the time of its unveiling, Amazon Prime was assailed by some as a permanently money-losing proposition in which customers pay a yearly fee and then would receive free two-day shipping at Amazon's expense. Eight years later, the program is widely considered to be a master stroke of retail genius, in which customers choose Amazon over other retailers as a matter of course. "Why order from anyone else?" is every retailer's dream.

Of course, two-day shipping is not the only option offered by Amazon and other retailers. Overnight delivery is often offered with a daily cut-off time of the type, "Order by 5:00 p.m., and receive your order tomorrow."

BY 2025, NEW HIGH-SPEED, HIGH-THROUGHPUT AUTOMATED ORDER PICKING SYSTEMS SHOULD BE DEVELOPED TO SUPPORT SAME-DAY DELIVERY

The newest battleground is same-day delivery: Orders received by a designated time will be delivered later the same day. Obviously, such promises can only be kept within a very limited distance of the warehouse or retail outlet. Amazon is currently offering same-day delivery in 11 major metropolitan areas, where it has built warehouses to support the service. Order cut-off times vary by city, from 7:00 a.m. in Indianapolis to 12:00 p.m. in Seattle. Orders are promised to arrive by 8:00 p.m. that day.[24] Walmart is testing a similar service called "Walmart To Go" in five cities. eBay offers yet another model called "eBay Now," in which valets pick up items from many local retail outlets and deliver them "in about an hour." The service is currently being tested in New York City and the Bay Area.

That different delivery models are being explored suggests that none of these retail giants yet knows the best formula for same-day delivery, nor are they sure how customers will respond. What does seem clear is that same-day delivery will be one of many future retail distribution channels and the implications for future material handling and logistics systems are significant.

Supporting widespread same-day delivery

In a same-day delivery system supported by a distribution center (as opposed to a valet shopping service such as eBay Now), extremely fast processing times are required of the order fulfillment system.

Capability: High-speed, high-throughput automated retrieval systems

For truly widespread adoption of same-day delivery, order fulfillment systems will have to attain two lofty goals at the same time—extremely low processing times and extremely high throughput. It seems impractical to solve this problem by "throwing labor at it" because of the cost. Needed are new, perhaps yet unimagined, automated order picking systems that deliver requested individual items within minutes. But these systems must also be able to accommodate the "last-minute rush" so frequently experienced right before a published cut-off time.

- By 2025, new high-speed, high-throughput automated order picking systems should be developed to support same-day delivery.

24. Amazon.com, http://www.amazon.com/gp/help/customer/display.html/ref=hp_leftv4ib?ie=UTF8&nodeId=201117750.

Capability: High-density storage systems

A second major challenge of same-day distribution is the need to locate distribution centers close to major metropolitan areas, where large tracts of land are typically scarce and expensive. In the "game of minutes" that will become same-day delivery, each additional mile between the DC and its metropolitan area is an additional 1 to 4 minutes of delivery delay, depending on traffic. The goal, then, is to achieve the nearly impossible: Locate a warehouse capable of storing tens of thousands of SKUs in a small space near a major metropolitan area.

Entirely new forms of high-density storage and retrieval systems, capable of storing thousands of SKUs and delivering individual items within minutes will be needed.

- By 2025, extremely high-density storage systems with rapid picking capability should be available and used in support of same-day distribution in densely populated areas.

BY 2025, THE 15 LARGEST CITIES IN THE UNITED STATES SHOULD HAVE AT LEAST ONE OPEN SHARED SELF-SERVICE PARCEL DELIVERY KIOSK NETWORK AVAILABLE FOR USE BY MULTIPLE RETAILERS

Supporting new forms of urban distribution

Urban consumers tend to lead busy lives with irregular schedules. They often do not own cars or may not use them frequently for shopping trips. Urbanization will continue to spur demand for new direct delivery modes for retailers to get products to consumers where and when it is most convenient.

Examples of such delivery modes for e-commerce include self-service parcel delivery kiosks (like Amazon Locker) and personal delivery where the recipient is a person and not an address. For these and traditional home-delivery modes, consumers will continue to demand faster service and push for same-day and same-hour deliveries.

- By 2025, most retailers serving urban areas should provide same-day direct delivery capability to urban consumers across one or more new delivery modes.

Capability: Open shared-use, self-service parcel delivery kiosks

Self-service kiosk delivery will continue to grow. In a kiosk system, a consumer specifies delivery of an order to a shared-use box that he or she can access with appropriate identification. Once the order is picked up, the box slot can be reused for another delivery. While technology for automated kiosk delivery is now available, it is impractical and inefficient for retailers to deploy separate kiosk networks. Collaborative kiosk networks, accessible by multiple retailers, should be developed and deployed. Systems for managing and sharing the capacity of such kiosks are required.

- By 2025, the largest cities in the United States should have at least one open shared self-service parcel delivery kiosk network available for use by multiple retailers.

Capability: Personalized delivery point specification systems

To enable consumers to specify where they would like a delivery, Web and mobile systems should be developed to enable consumers to easily update information about where they would like a delivery (address, kiosk location or real-time current location) for different product types. Common-use personalized delivery point specification systems accessible by multiple retailers should be created.

- By 2025, most U.S. consumers should have the capability to specify personalized delivery point information to multiple retailers.

Capability: Real-time current location delivery systems

For ultimate convenience, consumers may request a delivery at their real-time current location within a reasonable geographic boundary within a metropolitan or urban area. To enable such deliveries, real-time driver information systems must be developed and deployed to reschedule parcel deliveries continuously, based on a recipient's real-time location feed and to reroute delivery vehicles. Detailed location technology to pinpoint a recipient's location at a finer resolution than a street address may be required.

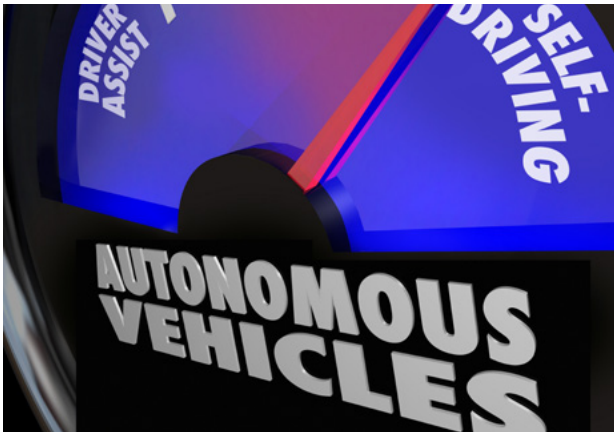
BY 2025, MOST U.S. CONSUMERS SHOULD HAVE THE CAPABILITY TO RECEIVE DELIVERIES TO THEIR REAL-TIME CURRENT LOCATION

- By 2025, most U.S. consumers should have the capability to receive deliveries to their real-time current location.

WORTH NOTING

Motor Freight Transport with Driverless Vehicles

The driverless vehicle is here and the implications are huge. There is little doubt about the technology. Driverless cars have been built and tested, and licensed cars are driving the streets of Nevada, California and Florida. Google's self-driving cars have already logged more than 300,000 miles.[25] Whether and how these vehicles will be integrated into our national system of transportation is another question.



THE ISSUES SURROUNDING SELF-DRIVING AND DRIVERLESS VEHICLES ARE MANY: WILL SOCIETY ACCEPT THE SELF-DRIVING CAR?

First, some definitions. The term "driverless car" has come to refer to a vehicle that navigates itself between locations in the presence of ordinary cars and other driverless cars, much like "autopilot" in airplanes. Whether or not the car has a driver onboard is a separate question. In the same way that an airplane on autopilot is flying itself with a pilot onboard, a "driverless car" might be driving itself with a driver onboard. Thus, we must make a distinction between a self-driving car that has a passenger/driver onboard and a driverless car that does not.

The issues surrounding self-driving and driverless vehicles are many: Will society accept the self-driving car? Will it accept the driverless car? If so, will self-driving and driverless trucks be allowed? If the latter, will special lanes be required? What will be the coverage of those lanes? Major interstates only? U.S. highways? Will driverless trucks be allowed to make commercial and residential deliveries or will they be restricted to long haul transportation between hubs? The answers to these questions will determine the implications of driverless technology on the material handling and logistics industry.

A possible scenario is that self-driving cars will be operating in normal traffic by 2025, but that those cars will be required to have a licensed driver onboard. It is likely that self-driving will be allowed only on certain roads (interstates, open highways, etc.) and perhaps only at certain times of day. We assume that the same rules will apply to trucks as to cars.

Implications for logistics systems

If self-driving trucks must be occupied, the implications for logistics systems will be fairly modest. *Continued next page »*

25. Wikipedia, Google driverless car, http://en.wikipedia.org/wiki/Google_driverless_car.

« Continued from previous page

- Trucks will still have to have licensed drivers, failing to ease the truck driver labor problem. It is possible, however, that attending a self-driving truck would be less arduous than traditional truck driving, and that driver retention would improve.
- Truck drivers are likely to require the same level of qualification, so the labor cost of transportation is likely to stay the same.
- Assuming attending drivers will have to be awake, established work/rest rules for truckers will remain intact, and the geographical reach of "a day's drive" will be approximately the same.

TRUCKS WOULD BE ABLE TO DRIVE AROUND THE CLOCK, THEREBY EXTENDING THE REACH OF A DAY OF TRANSPORTATION AND IMPROVING LOGISTICS SERVICE

Some benefits will arise, however:

- Self-driving and driverless cars and trucks are able to respond more quickly to dynamic driving conditions, which allows vehicles to follow one another more closely. This would have the effect of reducing traffic congestion, due to "tighter convoys" and increased density of flow.
- Self-driving trucks would not tire or get sleepy, so traffic accidents involving trucks likely would decrease significantly.

In the less-likely case that society accepts truly driverless trucks, the implications for logistics systems and the economy are profound:

- The truck driver labor crisis would (eventually) be averted, as retiring truck drivers are replaced by technology.
- Trucks would be able to drive around the clock, thereby extending the reach of a day of transportation and improving logistics service.
- Extending the geographical reach of a truck would eventually reduce the number of needed warehouses because the same level of service (in days to deliver) could be provided by fewer, larger warehouses. Alternatively, companies could provide higher levels of service with the same number of warehouses. In either case, companies nationwide would have an incentive to reconsider and perhaps redesign their supply chain networks.
- Finally, the total cost of transportation likely would go down, thus reducing the total landed cost of products on shelves.

Low-Cost, Low-Impact Material Handling and Logistics

CONSUMERS AT THE END OF THE SUPPLY CHAIN MUST ULTIMATELY PAY THE FINANCIAL COST OF LOGISTICS

Material handling and logistics are a vital part of modern commerce, because as long as goods are produced in one place and consumed in another, there will be a need to store, handle and move them. Nevertheless, this "time-and-place utility" comes at a financial and social cost. Broadly speaking, an ideal material handling and logistics system operates at the lowest possible cost and has the least possible negative impact on society. That is, it operates "without a trace."

Consumers at the end of the supply chain must ultimately pay the financial cost of logistics. Therefore, cost reduction has been an overriding focus of the industry for decades, and it will continue to be so into the indefinite future. Firms (and nations) that execute logistics operations at lower cost will always enjoy a competitive advantage.

The impact of material handling and logistics on society is more difficult to measure, but no less real. Trucks consume fuel, emit carbon dioxide, add to highway congestion and clog urban streets with deliveries. Distribution centers consume dozens of acres of valuable real estate with industrial buildings. A low-impact logistics system minimizes these negative social effects.

Supporting the needs of our economy and society through the year 2025 with low-cost, low-impact logistics will be an enormous challenge. Following, we describe new capabilities the material handling and logistics industry must develop to meet the needs of our nation. Capabilities are organized into four major areas: collaboration, urban logistics, technology and automation, and sustainability. In some cases, these capabilities would lead to lower costs. In other cases, they result in lower impact on society.

COLLABORATION

THE OBSTACLES TO WIDESPREAD COLLABORATION FALL INTO TWO CATEGORIES: TECHNOLOGY AND TRUST

Next to concerns about the workforce, participants in the workshops felt collaboration was the most significant challenge (or opportunity) facing the industry. All seemed to agree that significant reductions in the cost of logistics services will come only with dramatically new levels of collaboration between companies, both within and across industries, but they also recognized significant obstacles.

Collaboration allows freight carriers and shippers to reach further down into the supply chain to smaller and smaller companies. Current systems are only affordable by top tier carriers and shippers. Lower cost and standardized technology would allow small- to medium-sized businesses to operate with reduced inventory and shorter lead times. Most of these companies cannot operate with significant just-in-time processes today because a disruption in the supply chain leaves them little room to adjust.

Even the large companies who execute just-in-time (JIT) supply chains do not realize the impact they have on those further outside their immediate delivery schema. JIT suppliers rely on multiple sources for product and carry the inventory that the JIT manufacturer would normally carry. Future technologies will allow for more flexibility and less inventory, thereby reducing costs and increasing profits.

The obstacles to widespread collaboration fall into two categories: technology and trust. For effective sharing of transportation assets, systems must be in place to post the availability of capacity (an empty truck returning from Florida, for example), pricing or negotiating structures must be set, and funds must be transferred. This must happen while respecting sensitivity of data related to company operations.

The more difficult issue in large-scale collaboration is establishing sufficient levels of trust between participants, some of whom could be competitors.

Capability: Eliminating empty truck miles with shared transportation

The opportunity with the greatest potential benefit is shared trailer capacity. A 2011 survey by the National Private Truck Fleet Council estimates that 21% of private fleet truck miles were empty. Empty travel occurs for two main reasons: (1) shipments on

a trailer must leave before the trailer is completely full to meet service commitments, and (2) trailers must return empty to their point of origin after delivering cargo. Empty truck miles are a problem for a multitude of reasons including wasted fuel, labor and capital, and increased highway congestion.

The statistics above report only empty trailers, not partially filled ones. The less-than-truckload industry is a well-established and effective "common carrier" that consolidates small loads to achieve transportation efficiencies. The most significant opportunity for collaboration and sharing lies with private companies owning and operating their own transportation fleets.

- By 2025, a significant portion of shippers should be sharing transportation assets as a standard business practice. This includes a universally accepted and transparent allocation of costs.

BY 2025, A SIGNIFICANT PORTION OF SHIPPERS SHOULD BE SHARING TRANSPORTATION ASSETS AS A STANDARD BUSINESS PRACTICE

Capability: Optimizing the use of shared transportation assets

Optimization of the shared transportation assets must be widespread, so inbound and outbound logistics are seamlessly coordinated. Information on loads in transit and to be picked up must be available in real time and be transparent to all parties.

- By 2025, real-time tracking of transportation containers and real-time information on outbound loads ready for pick up should be available and capable of being viewed on a variety of shipper systems and personal communication devices. Logistics providers should have software systems that can digest this information to plan routes.

Capability: Increasing space utilization through shared warehousing

Large-scale collaboration is needed not just in transportation but also in warehousing. Again, means of collaborative warehousing already exist, but there is much room for improvement. Public warehouses and third-party logistics (3PL) warehouses are among current options.

At the industry level, one component of this could be industry and government partnering to form "logistics parks." In the *Outlook on the Logistics & Supply Chain Industry 2012*,[26] it is reported that such parks are being developed all over the world including the United States, China, Denmark (transport centers), Spain (logistics platforms), Germany (freight villages) and India (distriparks). In all instances, the purpose is to improve efficiency and reduce costs through shared assets among shippers, economies of scale and improved efficiency due to increased density, and more stable prices.

- By 2025, logistics parks and similar concepts should be in widespread use to support collaboration among shippers.

26. World Economic Forum, Outlook on the Logistics & Supply Chain Industry 2012, June, 2012.

As with most other collaborative efforts, an obstacle to accomplishing this goal is natural competition between firms in the same industry sectors.

Should these obstacles be overcome, more of these facilities should be pursued at huge multimodal intersections like the current ones in Los Angeles and Dallas. Smaller parks might accommodate only truck trailers, but still would provide the cost savings associated with better utilization of equipment and economies of scale.

- By 2025, there should be additional mega-logistics parks in the United States. There should also be a number of smaller parks that handle only truck trailers or a combination of truck trailers, rail and barge.

Editor's Note: Some in the industry believe it is unlikely that collaboration in material handling, logistics and transportation will be widespread in the United States, due to aggressive competition in our market economy. Others are more optimistic.

URBAN LOGISTICS

Urban communities are quite different from their suburban, small town and rural counterparts. They are conglomerations of densely populated neighborhoods, which are often demographically and culturally heterogeneous. Road infrastructure is often older and characterized by high levels of congestion as well as traffic restrictions that might prohibit truck traffic (or all motorized vehicle traffic) in downtown core areas. Retail districts might be densely packed with stores, with limited delivery access and parking.

Retailers usually operate smaller facilities in urban areas, due to scarce real estate. Urban retail stores with less square footage by definition will carry less inventory on display and in the backroom. Urban consumers may not own private automobiles and may arrive to shop on foot or by transit, and purchase fewer items each trip. In grocery retailing, urban shoppers may be more likely to purchase fresh and prepared foods, and may favor different product packaging formats.

Major U.S. retailers, including Walmart, Target and Office Depot, are now moving to open more urban small-format establishments. Convenience store operators, already experts in retailing with small square footage facilities, are continuing to add urban locations, and in some cases to shrink the size of the retail facility even further. As an example, 7-Eleven plans to grow from 20 outlets in Manhattan in 2012 to more than 100 by 2017.[27]

BY 2025, THE LARGEST URBAN AREAS IN THE UNITED STATES SHOULD BE SERVED BY OPEN SHARED-USE DISTRIBUTION FACILITIES OPERATED BY 3PLS OR OTHERS

Building logistics infrastructure to cost-effectively serve urban retailers will be challenging. Road congestion creates special challenges in urban environments. Delivery vehicles experiencing unexpected travel times may miss delivery windows. Parked trucks can add to surface street congestion. Limited parking for delivery vehicles can add variability to delivery service times. Many of these effects are exacerbated by the fact that low inventory carrying capacity leads to high delivery frequency at urban retail facilities.

Several capabilities could dramatically improve urban delivery logistics and most involve collaborative use of facilities.

Capability: Open shared-use distribution facilities

Crossdocking freight from larger trucks into smaller delivery vehicles (straight trucks, delivery vans, motorbikes, bicycles, etc.) can help reduce total freight delivery mileage in dense urban areas, mitigating some of the impact of frequent replenishment trips. Such facilities can also enable delivery by alternate modes that may be useful or necessary to handle parking congestion or restrictions, or roadway vehicle size restrictions. Open shared-use, crossdock facilities that can be dynamically scheduled for use by multiple, often competing retailers may enable more cost-effective last-mile distribution. To create such facilities, equitable and efficient space, door and labor allocation and scheduling systems need to be created that ensure information security for users.

- By 2025, the largest urban areas in the United States should be served by open shared-use distribution facilities operated by 3PLs or others.

27. 7-Eleven Plans to Break Global, Domestic Store-Growth Records Set in 2011, May 20, 2012, http://corp.7-eleven.com/Newsroom/2012NewsReleases/7ElevenPlanstoBreakStoreGrowthRecords/tabid/521/Default.aspx.

Capability: Dynamic vehicle routing and scheduling with predictive traffic information

To enable efficient routing and stop sequencing for trucks serving congested urban areas, advances are needed in the deployment of traffic-aware dynamic routing and scheduling systems. While some vendors claim today to provide such capability, advances are needed in the areas of short-term and long-term travel time forecasting given current conditions. Then, advanced forecasting models could be integrated into the systems that provide path-finding and stop sequencing, as well as feasible stop re-sequencing for vehicles already en route.

- By 2025, vehicle routing and scheduling software should use real-time traffic feeds; be capable of determining routes and schedules aware of predicted travel times; and support dynamic vehicle re-routing.

BY 2025, A SECURE PACKAGE SYSTEM SHOULD BE DEVELOPED AND DEPLOYED TO ENABLE UNATTENDED DELIVERIES TO UNSECURED LOCATIONS

Crowd-sourced urban delivery systems

An opportunity is arising in urban areas to use newly emerging transportation networks for small freight shipments, such as those for the delivery of small packages to consumers. A fleet of vehicles, which are partially managed and sometimes owned by a network operator, characterizes many emerging transportation networks. Examples of these networks include car-sharing fleets, dynamic ride-sharing services and smart phone-based car dispatch services.

Existing partially managed automobile fleets might be candidates for use for small package delivery, and/or dispatch technology might be developed to create a dedicated small package delivery system. Trust is clearly a major issue for such a system, but it is important to note that lightly regulated systems are already being used to provide personal transportation. Technological solutions might mitigate many trust issues.

Capability: Lightweight secure packaging

Secure packaging, such as a lightweight box that can only be opened by an authorized user and that includes integrated tracking and tracing technology, is a key enabler of crowd-sourced, last-mile transportation. Such advanced packaging would need to be inexpensive and likely reusable to be pragmatic. Modular systems where a person making a delivery could replace an empty box at a delivery address with a loaded box might be particularly effective.

- By 2025, a secure package system should be developed and deployed to enable unattended deliveries to unsecured locations.

Capability: Dynamic dispatch and fleet management systems for crowd-sourced pickup and delivery

New technology is needed to dispatch parcels dynamically in crowd-sourced systems. Key differences in crowd-sourced systems for pickup and delivery are the dynamic nature of available vehicles, strong heterogeneity in vehicle and driver capabilities and ratings for certain tasks, and the possibility that resources reject assigned tasks or have significant no-show likelihoods. Decision-support technology for dispatch and for managing trust and reputation for a crowd-sourced delivery fleet do not yet exist.

- By 2025, a dispatch and fleet management system for crowd-sourced pickup and delivery should be developed and deployed in practice.

THE MOST COMMON JUSTIFICATION FOR RESISTING AUTOMATION IS COST, BUT THERE ARE OTHER REASONS AS WELL, INCLUDING LACK OF FLEXIBILITY AND SCALABILITY

TECHNOLOGY AND AUTOMATION

The benefits of automation for material handling and logistics applications are many: Machines are more reliable, do not tire or make routine errors; conveyors move packages much more quickly than workers could carry them; automated systems incur lower labor costs; workers are less prone to occupational injuries; and, in many applications, automation is more cost-effective.

In spite of these benefits, manual material handling remains the norm in most industries today. The negative effects of manual material handling include undesirable, hard-to-fill jobs, high turnover costs, workplace injuries and product damage from mishandling.

The most common justification for resisting automation is cost, but there are other reasons as well, including lack of flexibility and scalability. (U.S. companies are particularly prone to emphasize very short payback periods as a criterion for committing to large automation projects.) It is important to realize that firms are behaving in their best interests by designing material handling and logistics systems with humans as the main actors. They are simply making profit-maximizing decisions in a competitive marketplace. Needed are advances in automation, robotics and other technologies that make these systems the preferred choice over humans for material handling.

Several new capabilities could turn the tables and lead to a significant expansion of automation in the industry.

Capability: More flexible and scalable material handling systems

A "flexible" material handling system is capable of quickly accommodating changes in product mix, storage capacity or throughput.

In many cases, automation is not as flexible as a manual system. For example, systems designed to accommodate a certain throughput or storage capacity are not easily modified to become more (or less) capable. An automated storage and retrieval system (AS/RS) with 10 cranes has a throughput capacity that cannot be altered without major (and expensive) changes to the system.

- By 2025, significant new systems for storage, handling and order picking should be developed that allow companies to reconfigure their systems rapidly to accommodate changes (both up and down) in throughput, SKU velocity and product mix.

BY 2025, AFFORDABLE ROBOTIC ORDER PICKING SYSTEMS SHOULD BE AVAILABLE THAT SUPPORT HIGH-THROUGHPUT, SINGLE-PIECE PICKING

Related to the concept of flexibility is the concept of scalability. A system is "scalable" when its capabilities can be incrementally increased or decreased as business needs dictate. Moreover, those incremental changes in capability should be inexpensive and easy to implement.

- By 2025, significant advances in scalability should have been made in storage, handling and order picking systems.

Capability: Robotic order picking

Even a cursory review of developments in the robotics industry suggests that we are at the beginning of a true revolution. Robots today are more capable, more intelligent and less costly than at any other time in history.

Robots in the material handling industry offer the ability to work tirelessly and without complaint at tasks that humans might find physically taxing, difficult or monotonous. Coupled with vision systems and artificial intelligence, future robots will be capable of performing many material handling tasks currently performed by humans.

Vision systems currently have the ability to discriminate individual items, but entire systems to identify items and manipulate a robotic picking arm to pick them are still immature, costly and slow. By 2025, these technical and economic obstacles will have been overcome according to *A Roadmap For US Robotics - 2013 Edition*.

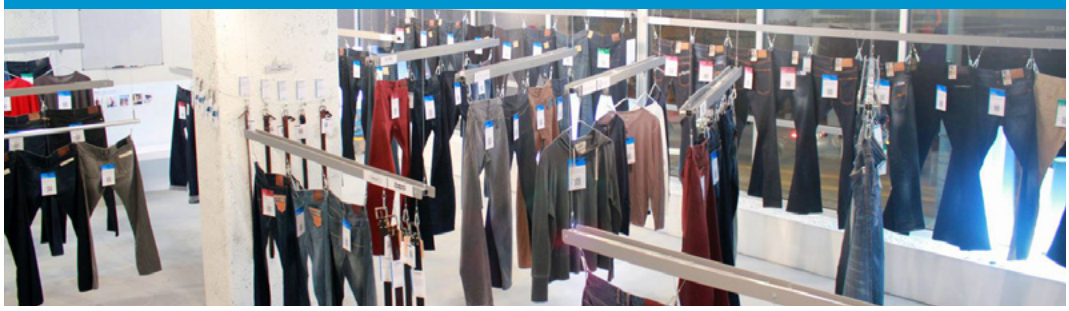
- By 2025, affordable robotic order picking systems should be available that support high-throughput, single-piece picking. These systems should be available in both part-to-picker and picker-to-part configurations.

Profile

HOINTER—A NEW MODEL FOR URBAN RETAIL

Hointer is an example of new concepts in retail enabled by material handling and logistics technology. In fact, Hointer is an example of several concepts discussed in this Roadmap—high-density storage, robotic order picking and leading-edge integration of mobile computing.

Hointer was started by Dr. Nadia Shouraboura, a former supply chain executive at Amazon.com, who thought there was a better way to sell clothing in metro areas. A Hointer store consists of a single pair of many styles of jeans, for example, hanging in a minimalist and small retail space. Customers enter, download an app on their smart phones and start shopping. After selecting a style, a customer scans the label and enters a size. The customer is instructed by the app to "Proceed to Dressing Room 3." In a matter of seconds, a backroom robot retrieves the jeans from a "micro-warehouse" and deposits them in Dressing Room 3, arriving before the customer gets there. Storage and retrieval of the item is completely transparent to the customer, to whom the entire process seems magical.



Capability: Wearable computing in the workplace

Workers in the material handling and logistics industry often work with their hands, so any requirement to interact with a control system or information device tends to reduce productivity by occupying the hands, diverting the eyes or disrupting focus and attention. An ideal control system provides needed information while allowing workers to remain focused, with both hands free for work.

Hands-free control devices such as light- and voice-directed picking have been successfully deployed in recent years. Voice picking in particular has been well received in order fulfillment systems. A voice-picking system consists of a headset and microphone worn by an order picker. Rather than carrying "pick sheets" containing items of an order, workers follow audible instructions from a computer-

generated voice, which instructs them on the next location to visit, which items to pick and how many to pick. Workers confirm instructions or ask questions directly to the control system. An interesting benefit of such systems is the ability to interact with workers in their native languages, which has helped integrate immigrant workers into the industry. In some warehouses, voice-picking systems give instructions in more than a dozen languages.

The promise of wearable computing offers opportunities for improved productivity and quality for the industry through "augmented reality." Google Glass and other future technologies will provide workers real-time, visual, hands-free access to documents, images, technical drawings, data feeds and even video—the entire Internet will be available upon speaking a word. The ability to send and receive feedback, call experts or check the status of another part of the plant or warehouse—all instantaneously and without interrupting the current flow of work—could transform the modern industrial workplace.

BY 2025, ECONOMICAL, HIGH-SPEED AUTOMATION TO LOAD AND UNLOAD TRUCKS SHOULD BE AVAILABLE BOTH AT THE CARTON AND PALLET LEVEL

- By 2025, control and execution systems featuring wearable computing devices should be developed and widely deployed in transportation, warehousing and manufacturing.

Capability: Motion-sensitive, interactive automation

Recent advances in the electronic game industry suggest that by 2025, entirely new industrial work environments could be possible. Coupled with new capabilities in autonomous control, artificial intelligence and robotics, motion- and gesture-sensitive technologies such as Microsoft Kinect could lead to productivity systems in which humans, machines and computers interact freely and effectively in completely new ways. Such work environments could go a long way toward attracting a new generation of tech-savvy workers.

- By 2025, highly productive systems employing interactive computing devices and robots should emerge in the industry, particularly in order fulfillment and manufacturing systems.

Capability: Rapid loading and unloading of truck trailers

In even the most highly automated warehouses in the world, it is common to see workers at the end of the line manually loading cartons into a truck or loading pallets with a forklift. For technical and economic reasons, the ability to load and unload trucks cost effectively has, for the most part, escaped the industry.

Although systems do exist to load and unload trucks today, they are not widely adopted for cost and speed reasons. True end-to-end automation to support high-speed delivery systems must include automated loading and unloading capabilities. Such systems could include radical new designs for tractor-trailers as well.

- By 2025, economical, high-speed automation to load and unload trucks should be available both at the carton and pallet level.

SUSTAINABILITY

As the initial enthusiasm cools for "all things sustainable," a new equilibrium is likely to emerge in which the underlying currents of the sustainability movement align with the cost and profit interests of corporations. Although there was some disagreement among participants in the workshops about the details, it is fair to say that the overall goals of sustainable development are universally shared: The material handling and logistics industry must operate in a way that leaves the environment in as good or better shape for our children than it was when we inherited it from our parents. The same will be true in 2025.

Capability: Assessing environmental impact

Any attempt to reduce the environmental impact of the material handling and logistics industry requires an accurate assessment of environmental impact itself. To this end, there is a need: (1) to specify in some unit of measure the relevant emissions released; and (2) to identify an environmental impact factor that might be expressed in monetary terms. Consideration of environmental impact could include effects such as deterioration of human health, loss of wildlife, agricultural effects and global warming. Any assessment of impact requires substantial care, because impact depends on the context with respect to the surrounding society and culture.

Life cycle assessment (LCA) tools already exist to help companies assess the impact of their operations on the environment. These tools should be extended to address the details of material handling and logistics. The greater challenge, however, is to spread the word within the industry that such tools already exist.

- By 2025, the industry should have developed and widely deployed standard, accepted metrics with respect to environmental impact.

Capability: Environmentally conscious transportation

One of the factors that contribute to emissions generated by the material handling and logistics industry is the long distances traveled by trucks and other vehicles. As the industry continues to reduce the cost of transportation by reducing miles driven, the environment will benefit.

But, more can be done. There is a natural tension between shippers, who seek to consolidate shipments for transportation efficiencies (and perhaps unintentionally for environmental benefit), and customers who want what they want when they want it. Through increased awareness or carefully designed pricing strategies, changes in customer behavior could lead to reduced impact on the environment.

- By 2025, consumers should have a better understanding of the environmental consequences of their choices.

BY 2025, LEED-CERTIFIABLE BUILDINGS SHOULD BE COMMONLY BUILT AND RENOVATED FOR MANUFACTURING AND DISTRIBUTION

Capability: Environmentally conscious packaging

A significant amount of solid waste generated by the industry comes in the form of packaging. There is a need for new approaches to reduce the amount of packaging required and for new packaging materials and approaches that support future material handling and logistics requirements. Packaging must be capable of preventing product degradation due to environmental factors, preventing physical damage, supporting new material handling equipment, and improving space utilization within unit load containers.

- By 2025, environmentally sensitive materials should have packaging that prevents degradation and physical damage. Such packaging should make better use of space in standard containers.

Capability: Environmentally conscious equipment and facilities

After the energy sector, transportation and logistics is the most visible industry in the global effort to reduce carbon emissions. To reduce environmental impact, there is a need to adopt more alternative energy and hybrid vehicles for over-the-road transportation and for material handling equipment inside facilities.

- By 2025, the transportation industry should have new vehicles that are lighter, use less energy and run on alternative forms of energy.
- By 2025, the material handling industry should have developed new equipment that uses less energy.
- By 2025, LEED-certifiable buildings should be commonly built and renovated for manufacturing and distribution. LEED certification should include scoring for equipment choices based on the types of services they provide (specific factors for distribution centers rather than, for example, hospitals).

WORTH NOTING

Additive Manufacturing

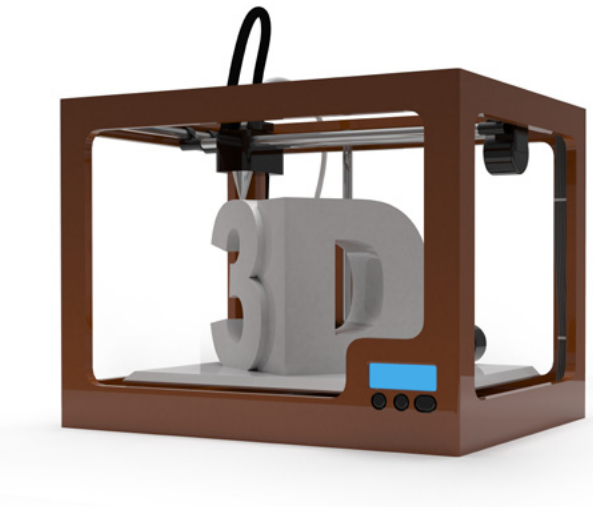
Additive manufacturing (often called "3D printing" in the popular press) is the process of forming a three-dimensional object from a powder or other raw, bulk material. The type of object formed is almost arbitrary—as long as it can be represented in digital form.

The ability to create "almost anything out of almost nothing" understandably has captured the attention of the public, and the potential implications are profound. Entire new models of manufacturing could spring up, with "plants" located in basements and garages everywhere. It is also possible that economics or regulation would constrain the technology to more traditional, large-scale manufacturing methods and sites.

ADDITIVE MANUFACTURING IS LIKELY TO ADD TO THE TREND TOWARD "MASS PERSONALIZATION," AS CUSTOMERS GAIN THE ABILITY TO CUSTOM-DESIGN PRODUCTS IN SOME CASES

Implications for logistics systems

Where this technology will lead by the year 2025 is a matter of speculation, but some things are pretty certain. First, additive manufacturing is likely to change the spare parts industry, allowing firms to eliminate stock of legacy items and to replace them with digital representations and the ability to make on demand. For example, makers of industrial vehicles such as John Deere and Kubota currently must hold replacement parts for decades because the vehicles they produce are in service for that long. Holding thousands of part types for hundreds of vehicles over decades leads to enormous quantities of slow- and non-moving inventory, much of which could be eliminated by additive manufacturing.



Second, additive manufacturing is likely to add to the trend toward "mass personalization," as customers gain the ability to custom-design products in some cases. This trend would increase the demand for B2C distribution channels.

Third, significant additive manufacturing would create the need to handle and transport bulk raw materials to new points—perhaps many new points—of manufacture. It is conceivable that many of these new "manufacturing plants" would be very small, and that bulk replenishment would be in very small batches.

The Workforce of Tomorrow

Despite the potential of dramatically improved processes and technology for material handling and logistics systems in the coming years, much of the work in the industry will continue to be done by a human workforce in the year 2025. Moreover, other aspects of this Roadmap, such as mass personalization, will require levels of operational flexibility that can only be handled by a skilled and creative workforce. In other words, people will continue to be vital to the industry in 2025.

Currently, the material handling and logistics workforce is being pinched from two directions—demographics and skill sets.

On one side, the retirement of baby boomers will substantially dampen growth in the labor force for the next decade. Although not unique to material handling and logistics, this issue is especially pressing because so many current workers are close to retirement.

There is also the issue of turnover in existing positions. Annual turnover in the warehousing and distribution industry is estimated to be 25%, and the issue is even more acute among truck drivers, where turnover is estimated to have been 98% in 2012.[28] Growth of the logistics industry makes the problem even more challenging. Total national logistics costs increased by approximately 3.2% in 2012 in keeping with growth of GDP.

The result is a constant pressure to fill positions. Unless the industry makes significant changes, the gap between the workforce needed and the workforce available will continue to grow between now and 2025.

28. American Trucking Associations, press release, Oct. 7, 2013.

The other pinch point is the lack of necessary skills in the available talent pool. Some of the imbalance is caused by the retirement of existing workers and loss of their attendant knowledge base and skills. Unfortunately, the imbalance is compounded by a noticeable lack of skills among those who are either less experienced in the field or those who want to join it.

In manufacturing alone, a recent survey shows that 67% of manufacturers report a severe shortage of qualified workers.[29] Furthermore, 56% of respondents expected that shortage to become worse in the next few years. It was also estimated that 5% of manufacturing jobs—600,000 positions nationally—go unfilled for lack of qualified workers.

5% OF MANUFACTURING JOBS—600,000 POSITIONS NATIONALLY—GO UNFILLED FOR LACK OF QUALIFIED WORKERS

It is worth noting that these two workforce issues were voiced at all four regional events held to gather data for this Roadmap. In fact, the participants who met in Atlanta clearly considered workforce development to be the top priority for the industry in coming years. And at all four events, workforce was one of the top two or three priorities.

While those are two significant challenges, the industry has a broad range of opportunities it can develop to be in a different position by 2025. Not the least of these opportunities is a growing recognition of the appeal of a career in material handling and logistics, or supply chain. *Fortune, Business Week,* and *U.S. News & World Report* have all identified the field as "hot," a "top career" or "the next big thing."

Traditionally, the demographic profile has not been especially broad. In all employment sectors—operational, engineering and management—older males dominate, and not by a small percentage. In many cases, more than 80% are male.[30]

29. Deloitte and The Manufacturing Institute, "Boiling point? The skills gap in U.S. manufacturing," pg. 1, 2011.

30. Material Handling & Logistics, "MH&L's 2013 Annual Salary Survey: Can't Get Enough Satisfaction," pg. 1, Mar. 20, 2013.

That imbalance opens the door to a broader demographic profile for the industry through a range of initiatives. Such an expansion would be based on greater diversity with regard to gender, age, people with disabilities and veterans, to name a few. A range of company-based and national programs has already demonstrated the potential that such programs would unlock.

Regarding the skills issue, there are initiatives underway to educate and train people for a career in material handling and logistics (e.g., the Technical Career Education Program, a joint program of MHI and the Material Handling Education Foundation). Programs range from training young students to retraining people for a new career. The programs also include on-the-job retraining for those already in the field.

THE ENTIRE WORKFORCE WILL HAVE TO RESPOND TO A RAPID RATE OF CHANGE IN TECHNOLOGIES AND PRACTICES REQUIRED TO HANDLE AND MOVE GOODS

Between now and 2025, the entire workforce will have to respond to a rapid rate of change in technologies and practices required to handle and move goods. Those new technologies and practices, discussed in other sections of this Roadmap, will be essential to meeting many of the challenges in material handling and logistics in coming years. They will require a much more technically savvy workforce. In turn, that must result in a range of new education and training programs to develop the needed skills in the workforce.

The opportunity goes beyond expanding and building out these programs. Most current programs are one-offs that have little to no linkage to similar efforts elsewhere. A national initiative is needed to leverage and deploy these programs on a scale that can meet current and near-future needs as well as those needs that are unknown today but may emerge by 2025.

PROFILE OF THE MATERIAL HANDLING AND LOGISTICS WORKFORCE

Employment in the industry falls into three broad sectors: operational, engineering and management.

Operational jobs fall into two groups, both of which perform the tasks required to handle, move and transport goods. One group is the people who work within the four walls of the warehouse, distribution center and manufacturing site. They load and unload trucks with goods, move goods around the facility, make things and fill orders. The other group is composed of their counterparts who transport goods between facilities by truck, air, sea and railroad. These workers drive the trucks and other vehicles from point A to point B.

Education and training for both groups is typically on the job and occasionally includes an associate degree or higher. However, many positions do require certification for a defined set of skills.

Although some workers remain at a company for long periods of time, workers in operational jobs generally have high turnover because the work is physically demanding and, in the case of truck drivers in particular, may require employees to be away from their families on a regular basis. These are generally not high paying jobs. According to the Department of Labor, the median annual pay range in 2012 was $28,230 to $30,270.[31]

Engineering is comprised of the people who design the movement and handling systems and keep them running on a day-to-day basis both within and outside the four walls of facilities. Four-year college degrees are essential and commonly include packaging, industrial, mechanical, electrical and systems engineering, as well as business logistics. Advanced degrees are not uncommon.

Management is the group that oversees the planning, buying and operation of the handling and transportation systems, operations and departments. This group is also responsible for managing the people who move and handle goods. Some carry supply chain titles. Managers are also responsible for ensuring that the material handling and logistics systems in use support corporate objectives and priorities. College degrees for managers are standard (except operational supervisors and managers) and include business as well as engineering.

Turnover in the engineering and management sectors is generally less than 10% annually. Pay is also higher, with industry trade magazine salary surveys generally showing the median to be about $80,000. Job satisfaction was recently put at 98% by nearly 1,000 respondents to one of those surveys.[32]

The typical material handling and logistics executive is a white male in his 50s who has a four-year degree, has been with his current company six to 10 years and has 30 years of experience in the industry.[33]

31. Bureau of Labor Statistics, Industries at a glance—Warehousing and Storage: NAICS 493, Earning by Occupation, 2013.

32. Modern Materials Handling, "Modern's 5th annual salary survey," pg. 1, Sept. 1, 2012.

33. Material Handling & Logistics, "MH&L's 2013 Annual Salary Survey: Can't Get Enough Satisfaction," pg. 1, Mar. 20, 2013.

WORKFORCE DEMOGRAPHICS: CHALLENGES AND CAPABILITIES

The material handling and logistics workforce has three major challenges in its demographic makeup going forward:

- a rapidly changing workforce,
- inadequately defined career paths, and
- lack of appeal to several potential labor pools.

Each of these challenges will lead to a range of new capabilities that need to be developed in the industry by 2025.

A rapidly changing workforce

Given the workforce profile, it is clear that baby boomer retirements are going to affect the engineering and management sectors significantly between now and 2025. High turnover in the operational sector will ensure an even greater level of turnover.

Capability: Active prospecting for future employees

Traditionally, filling a position is not a concern at most companies until there is a position to fill. In the meantime, there is not much focus on reaching out to prospective employees. Going forward, companies will have to make employee prospecting an on-going activity, keeping in touch with potential employees over time. Competition for people from other fields will make this an imperative.

- By 2025, active, on-going programs and strategies for finding employees should be standard practice across the industry. Both regional and national recruitment strategies should be part of this solution.

It is possible that special employment services could arise to meet this need.

Capability: A national, online employment center

Today there are many different electronic employment services, but they are typically stand alone and not linked to related opportunities in the field. Most of these services are simple job postings rather than true search engines for material handling and logistics positions with detailed requirements. Often it is difficult for candidates to know if they qualify for the job or even what the job entails.

- By 2025, a dedicated national employment center should be the go-to online source of jobs in all of the material handling and logistics sectors. It should identify openings as well as where the position fits in a particular, industry-defined career path.

Capability: Increasing awareness of careers in the field

An industry-wide push to expose students to material handling and logistics earlier in school is a great need. Today, small numbers of students first hear of material handling and logistics at the high school level or upon graduation. Others hear of the field when they enter college. Still others are relatively unaware of the field as a career path until after graduation. There is no broad promotional campaign to position the industry before the general public.

- By 2025, the industry should develop, fund and aggressively promote careers in material handling and logistics to the general public, with a special emphasis at schools. This program, which would start no later than high school, would be the cornerstone of a coordinated national effort to make students aware of these careers as a path to a high standard of living.
- By 2025, academic programs in material handling and logistics in community colleges and high schools should be commonplace. These programs would not be confined to operational subjects. They should also introduce students to engineering and management subjects, helping all to become interested early in their working lives.

BY 2025, ACADEMIC PROGRAMS IN MATERIAL HANDLING AND LOGISTICS IN COMMUNITY COLLEGES AND HIGH SCHOOLS SHOULD BE COMMONPLACE

Inadequately defined career paths

As the industry works to bring new people of all ages into its workforce, the challenge is to overcome a perception that joining it might not result in a career with suitable rewards. As noted in the previous section, the emphasis is too often on a particular position rather than on a position as part of a career path.

Increasingly, people want to know up front where a particular job might lead them. Lack of definition makes it even more difficult to convince prospective employees that a position is attractive at a time when new people will be essential to the industry.

Capability: Career development programs

- By 2025, there should be a national career development program for the industry. It would be a partnership of employers, associations and others to make career paths clear to all those in the industry and looking to join it. Outreach resource centers would figure prominently. This program would be linked to the national employment center and to the program to introduce students to the rewards of a career in the industry.
- By 2025, career development should be a major emphasis at key industry associations. Programming should not just identify career paths but should help people plan their careers.

Lack of appeal to potential labor pool

The material handling and logistics industry faces a great challenge to become appealing to groups that have not traditionally been part of its workforce in significant numbers. To move forward, the industry must appeal to a different profile of people or else a significant percentage of jobs will go unfilled. Such a shortage would be in addition to a skills shortage (see next section).

Capability: Outreach to new demographic groups

- By 2025, there should be a significantly different profile of the typical employee in material handling and logistics. Four groups in particular—women, workers under 35, people with disabilities, and veterans—should especially be targeted by the recruitment and career path development programs. There should be a special focus on mentoring and promoting these individuals.
- By 2025, women should account for a significantly increased percentage of the material handling and logistics workforce.
- By 2025, workers under the age of 35 should account for a significantly increased percentage of the workforce. This will require the industry to develop programs that will first interest these people in the industry and then engage them in its activities. Today, both of those new capabilities are wide gaps. Also critical will be broad use of leading-edge technology to reduce or eliminate undesirable and unappealing activities.
- By 2025, employment of people with disabilities should be commonplace in the industry. Using pilot programs now in place at Walgreens[34] and elsewhere, people with disabilities should perform at the same level as those without disabilities.
- By 2025, there should be an industry-wide program to recruit and employ veterans, many of whom are leaving the military with experience in this field.

34. Walgreens Next Generation Distribution Centers, http://www.walgreens.com/topic/sr/distribution_centers.jsp.

WORKFORCE SKILLS: CHALLENGES AND CAPABILITIES

The material handling and logistics workforce has three significant skills challenges going forward:

- an undersized training/education network for the projected number of jobs,
- inadequate skills in the existing and entering workforce, and
- a poorly connected training and education network.

Each of these challenges should lead to a range of new capabilities that must be operationally effective by 2025.

THERE IS A CRITICAL NEED TO ADVANCE THE FIELD THROUGH UNIVERSITY RESEARCH RELATED TO MATERIAL HANDLING, LOGISTICS AND SUPPLY CHAIN TECHNOLOGIES

An undersized training/education network for the projected number of jobs

Despite the need, material handling education at four-year schools is in danger. Of the top 100 universities that supply this field with graduates, only 40% offer at least one dedicated course in material handling[35] and that number has been declining in recent years.

Looking ahead to 2025, the education gap is likely to become more pronounced. In fact, jobs in the field are changing as material handling, logistics and supply chain receive more recognition in companies. Once seen only as cost centers, these activities are increasingly, but not universally, seen as strategic assets. "Curiously, more than 60% of surveyed companies view logistics as 'nonstrategic.' At the same time, however, expectations for near-perfect performance are placing increasing stress on global logistics organizations."[36]

At the same time, a growing number of new job classifications is being developed as the demands of the field grow and expand. Some of these are the result of new responsibilities in the supply chain, and others are the result of new technology, some of which improves work conditions. New job classifications include sustainable logistics services, compliance, risk management and security.

Capability: A material handling and logistics education consortium

- By 2025, a material handling and logistics education consortium should be actively working with community/technical colleges and four-year schools. This should expand the number of schools offering degrees, increase the number of core courses and the total number of graduates. Strong industry participation should ensure the most appropriate courses are offered and that graduates arrive at the workplace ready to contribute on their first day.

35. College Industry Council on Material Handling Education, "State of Material Handling Education Report 2013."

36. Gartner, Inc., "Predicts 2012: Global Logistics."

Capability: Formal, recognized job classifications

- By 2025, new curriculum and certifications should be developed to codify emerging job classifications. The model for this is the National Center for Supply Chain Technology Education.

Capability: Funding for university research

There is a critical need to advance the field through university research related to material handling, logistics and supply chain technologies. These advances would lead to the development of new tools to aid the effectiveness of the workforce. Improvements could range from worker well-being to elimination of redundant and dangerous tasks. As a result, people would no longer have to perform tasks that machines can do better, which would open the door to deploying the available workforce to jobs that people do better than machines.

- By 2025, there should be a Material Handling and Logistics Research Council with significant funding for academic research that has a strong potential to affect the industry.

BY 2025, AN ONLINE REGISTRY OF RESOURCES IN THE FIELD WILL BE THE CENTRAL CLEARINGHOUSE FOR PEOPLE TRYING TO LAUNCH OR ADVANCE THEIR CAREERS

Inadequate skills in the existing and entering workforce

At all of the data gathering workshops for this Roadmap, participants were broadly disappointed with the skills quality of job applicants. They were also concerned about the ability of people already on the job to keep pace with technological change in the field. This was true across all three sectors of the field: operational, engineering and management.

Other concerns included problem-solving abilities, situational response skills and abstract reasoning. Few were aware of companies investing significantly to close the gap. However, they have high expectations that employees arrive at work ready and able to keep pace with the rate of change over time.

The rate of change is especially critical as the field continues to rely increasingly on technology to reduce and eliminate unnecessary physical demands on people. Technology is also a tool being used to organize, streamline and share various activities in the field.

Most disappointingly, participants did not see today's educational institutions and certification programs as positioned to close the skills gap.

Capability: A national skills center to address the skills gap

On-the-job training will be required of companies in any feasible long-term solution. Nevertheless, there is a need to build a network of certifying bodies to incorporate certifications from associations and related programs in place today. It would also generate a range of new, valuable certifications for the industry. Industry would also recognize these certificates as valuable to an individual's career advancement and reward them financially for achieving a nationally recognized skill set.

- By 2025, a national skills center for material handling and logistics should be generating 50,000 certificates a year for people in the industry or those who are seeking to enter it.
- By 2025, the national skills center should be working in close partnership with the national education consortium (previous section) to develop a cohesive program that standardizes expected skills and abilities nationally.

BY 2025, AN ONLINE REGISTRY OF RESOURCES IN THE FIELD WILL BE THE CENTRAL CLEARINGHOUSE FOR PEOPLE TRYING TO LAUNCH OR ADVANCE THEIR CAREERS

Capability: Retraining workers from other fields

- By 2025, a program dedicated to retraining people from other work fields should be generating 20,000 certificates annually.

Poorly connected education network

As mentioned in the introduction to this section, there is too little interconnection between many of the field's educational institutions and programs. Many programs are one-offs, many are very local, and few have much synergy with others.

In some cases, this is just the nature of how education has developed in the field. In other cases, it is purely accidental.

Some of the capabilities mentioned earlier will make strides to address the need to more fully integrate these programs. The following capability would add still another dimension to changing the current profile of the education network.

Capability: An online registry of resources

- By 2025, an online registry of resources in the field will be the central clearinghouse for people trying to launch or advance their careers. It will tie together the centers and consortiums and other national efforts already discussed.

Where Do We Go From Here?

The goal of the Roadmap is not to prescribe solutions to future problems, but rather to point the way by describing the conditions the industry is likely to face in the years up to 2025. As such, the Roadmap avoids detailed recommendations, which the many stakeholders in the industry will address. Nevertheless, a few broad suggestions for "next steps" seem clear.

OUR COMPETITION-BASED ECONOMY RELIES ON INDIVIDUALS AND COMPANIES TO PROVIDE INNOVATIONS THAT MEET MARKET NEEDS

Many of the issues in the Roadmap involve technology, which is advancing at a pace few can comprehend. During the writing of this document, for example, Amazon announced its Prime Air experiment with small, autonomous quad-copters. By 2025, such innovations will either be viewed as crazy ideas that failed, or they will be part of the daily fabric of our economy. No one knows. And so it is with many ideas we currently label "futuristic." The marketplace will determine their contributions.

Our competition-based economy relies on individuals and companies to provide innovations that meet market needs. Consequently, many of the technology issues identified in the Roadmap will be addressed by individual entities. It is the editors' hope that the Roadmap will serve as a catalyst that sparks the imagination of those developing tomorrow's products and services.

There are other problems, however, with solutions that are beyond the abilities of a single company or organization. The Roadmap identifies three broad categories that will require many actors to come together in new ways:

Collaboration

Workshop participants felt strongly that significant cost savings are possible if companies can work together to share information and assets they currently view as private. Empty truck miles and low warehouse utilization are invitations for companies, associations and governments to work together for mutually beneficial solutions.

Standardization

It is natural for companies to want to differentiate their product offerings, but customers often suffer when physical and information systems do not work together as well as they could. Workshop participants, particularly end users, expressed a desire for standardized systems that "just work together." For progress to be made on this front, companies and their associations must begin new initiatives that bring together end users, suppliers and others to work for the greater good.

THE ROADMAP IDENTIFIES MANY WAYS THE INDUSTRY CAN BEGIN TO ADDRESS WORKFORCE DEVELOPMENT. PARTICIPANTS AT THE WORKSHOPS BELIEVED THIS IS ALREADY A MAJOR AREA OF CONCERN, WITH MORE TROUBLE AHEAD IF POSITIVE ACTION IS NOT TAKEN SOON

Workforce development

The Roadmap identifies many ways the industry can begin to address this vital area. Participants at the workshops believed this is already a major area of concern, with more trouble ahead if positive action is not taken soon. All members of the industry have an interest in making progress here.

Government also has a role, both with regard to regulation and to funding pre-competitive research. Participants at the workshops acknowledged a gap between university research and industry needs, and many pointed to German universities as a model for government sponsorship of applied research that has a significant impact on the industry. In the United States, the National Science Foundation has long been the agency supporting university research at the federal level, but the Foundation by its nature funds research on basic scientific questions rather than applied questions.

Germany has an equivalent organization, but it also funds 60 Institutes of the Fraunhofer Society to conduct applied research tied directly to industry. The government provides approximately 30% of the funding for the society, with the remaining 70% coming from industry sponsors. Because the government funding is long term, Institutes of the Society are able to take on large-scale projects over many years, rather than focusing on more narrow questions in a series of competitively awarded projects. Such a long-term commitment to applied research would go far toward allowing the material handling and logistics industry to answer many of its most pressing questions.

How the Roadmap was Written

THE PROCESS

Workshops to develop content for this Roadmap were held in the summer of 2013 in Atlanta; Washington, D.C.; Los Angeles and Chicago. Participants represented a variety of backgrounds within the industry: end-users, suppliers, consultants, academics and representatives from government and NGOs.

Participants spent approximately eight hours over two days discussing trends, challenges and capabilities that will determine the industry's future in 2025. Discussions were held in facilitated groups of six to eight participants. Scribes documented the results of these table discussions in digital documents, which were later compiled and synthesized into a summary (one for each workshop). Summary documents were sent to participants for validation.

After the final workshop, a small team of writers assembled for a one-day interpretation and synthesis session. The writing team identified major trends and needed capabilities, and then developed the basic structure of the Roadmap document. Writers developed separate portions of the document, which were assembled and edited by the editor-in-chief.

Two drafts of the Roadmap were posted for industry comment and feedback for periods of two weeks each. Comments were incorporated into the final draft.

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