NEW YORK STATE ASSOCIATION OF MPOs
FREIGHT WORKING GROUP
May 13, 2020
Webconference
2:00 PM – 3:30 PM

MEETING NOTES

1. Participating

- BMTS – Leigh McCullen
- CDTC – Christian Bauer (Chairman)
- DCTC – Mark Debald, Emily Dozier
- ECTC – Nicolette Wagoner
- GBNRTC – Rich Guarino
- GTC – Jody Binnix
- NYMTC – Gerry Bogacz, Leslie Fordjour
- OCTC – Ashlee Long
- SMTC – Mike Alexander (Co-Chair)
- WJCTC – Scott Docteur, Al Ricalton
- NYSDOT – Jim Davis, David Rosenberg
- FHWA –Gautam Mani
- T.Y. Lin International (NYSAMPO Staff Support) – Richard Perrin
- Cambridge Systematics (NYSAMPO Staff Support) – Brian Stewart

1. Roll Call

Bauer opened the meeting and conducted the roll call.

2. Impacts of E-commerce and Technology on Goods Movement & Logistics

Bogacz presented (see Attachment A) on research conducted by NYMTC as part of its regional freight plan, which is a component of its long range plan update, noting that the research was conducted prior to the current public health emergency. Bogacz discussed the following topics:

1. E-Commerce: growing faster than traditional retails sales and growth could accelerate even more with COVID-19 pandemic as consumers avoid stores. Faster delivery times ("Amazon Effect") in part due to decentralization of distribution facilities and greater use of truck and air shipments.
2. Less-Than-Truckload: Industry has grown since the end of the Great Recession (summer 2009) via optimization of shipment size and role in home deliveries, resulting in more frequent truck trips including in peak hours. Shorter trips more attractive to younger operators (i.e., drivers) than full-load, long-haul trucking.

3. Vehicle Automation: Federal and state regulations will determine timeframe and extent of use. Results in cost savings (reduced labor costs) and improved productivity (hours-of-service regulations less applicable). Impacts on safety and distribution networks unknown. This automation is not limited to trucks.
4. Warehouse Design & Automation: Trends include more distribution centers that are smaller in size and in some cases use buildings originally constructed for other purposes such as office space (i.e., micro-warehousing). Service is trumping cost, making urban locations more competitive.
5. Distributed Manufacturing: 3D printing and other forms of Additive Manufacturing (AM) are advancing technologically with implications for future supply chains and business location decisions (i.e., manufacturing could be on-shored, including in large metropolitan areas). The raw materials to be processed/manufactured would be suitable for bulk transport by rail and water.
6. Congestion Pricing: In reviewing results from London, changes in traffic entering the central city were more pronounced for passenger vehicles than those carrying freight. This resulted in increased costs for goods that would need to be passed on to customers or affect the profits of carriers.
7. Alternative Fuels: Options exist for all modes – truck, rail, marine, and air – with impetus, extent, and timing of deployment varied by mode.

Associated recommendations are categorized into 1) Planning Initiatives; 2) Project Planning and/or Environmental Reviews; 3) Programmed Improvement Projects; and 4) Policies and Programs.

Bauer asked if NYMTC had additional information that it could share with the group. Bogacz responded that an associated technical memorandum has been developed, which can be made available to the group (see Attachment B). Bogacz stated that forecasts of e-commerce activity were difficult to obtain. Perrin asked if this is due to cost. Bogacz responded that there are limited sources but cost is not an issue. Perrin noted that AM is about more than business-to-consumer transactions. Bogacz responded that it is beyond even business-to-business and includes consumers being able to print their own goods and not rely on printers owned and operated by businesses.

3. Effects of COVID-19 on Freight

Perrin introduced this item pointing the group to the materials that were provided with the agenda: *COVID-19 Impacts on the Trucking Industry* from the American Transportation Research Institute and OOIDA Foundation and COVID-19 resources from the American Association of Railroads and World Ports Sustainability Program. Bauer provided the following highlights from a webinar by INRIX on its report *An Analysis of Long-Haul Freight Movement During A Pandemic:*

- Some freight movement is strong: groceries, some medical, and essential supplies; other freight movement is weak or gone: retail, fuel, and automobiles.
- Passenger travel is down 46 percent nationwide, freight travel is down 13 percent nationwide.

- A nine percent decline in the northeast region, with New Jersey and Rhode Island affected the most.
- Gulf Coast states have had the biggest decline, possibly linked to a decrease in oil production.

- Congestion is down, travel speeds are up.
  - New York City: 32 percent increase in travel speeds in the AM Peak and 40 percent increase in the PM Peak

Alexander suggested keeping the impacts of COVID-19 on freight as an item for the group both on future meeting agendas and in between meetings as members and the staff support consultant identify items of interest that can be shared via email.

4. Topics of Interest for 2020-2021 Meetings

Bauer introduced this item by reminding members that the group's work plan for the current year includes a survey of members to identify topics of interest to be discussed at future meetings. Perrin added that the survey will be conducted online prior to the July 8, 2020 meeting with results presented at that meeting. The survey will also include questions on the initiatives and trainings that members have recently completed and expect to undertake in the current State Fiscal Year. Bogacz responded that he concurred with prior comments regarding monitoring the impacts of the current public health crisis on freight. Bauer suggested an important element of that is the availability of current data and information (specifically, big data resources) to determine what has changed and how it has changed. Bogacz proposed discussing the impacts of COVID-19 on future freight demand, market trends, and advances in technology as they relate to project evaluation and selection. Guarino offered to present the GBNRTC freight update at the October 27, 2020 meeting.

5. Updates from Stakeholders

Bauer reported that the next CDTC Freight Advisory Committee meeting is scheduled for May 20, 2020 and will be held via webconference. Presenters will be discussing COVID-19 impacts on their businesses and group members are welcome to attend.

Alexander reported that the SMTC long range transportation plan is scheduled for adoption in September 2020 and will include an updated freight narrative that highlights SMTC's Freight Transportation Profile findings. Work had been halted temporarily on the large distribution center in Clay. Work on that facility and the inland port at the CSX DeWitt yard are currently underway.

Bogacz reported that NYMTC is advancing its clean freight corridors study and multi-state freight land use study. Both of these initiatives are recommendations in the NYMTC Regional Freight Plan.

7. New Business

Bauer asked the group if anyone had new business. There was none.

8. Adjourn

Bauer adjourned the meeting at 3:01 p.m.

Attachment A

NYMTC Regional Freight Plan

Supplemental Assessment of Impacts of E-commerce and Technology on Goods Movement & Logistics

Supplemental Research

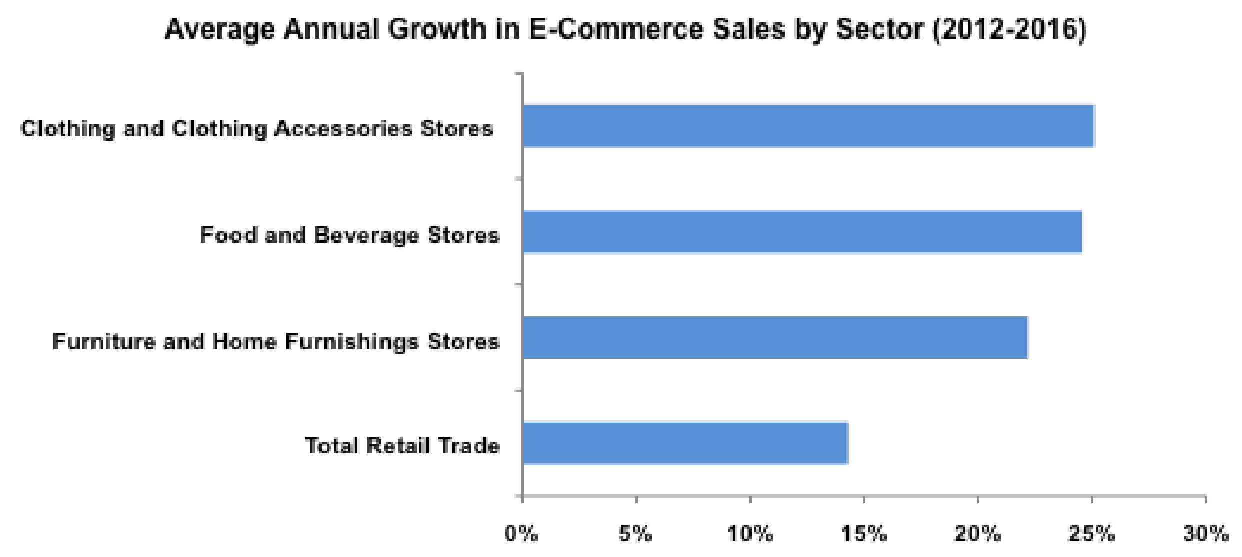
- For each topic, a review of trends, effects on supply chains, and approximate timing of the effects

  1. E-Commerce
  2. Less-Than-Truckload (LTL)
  3. Vehicle & Facility Automation - AV technologies, autonomous delivery, PTC, autonomous trains, marine terminal automation, warehouse design and automation
  4. Distributed Manufacturing

- CAVEAT: trends and forecasts are all pre-COVID-19!

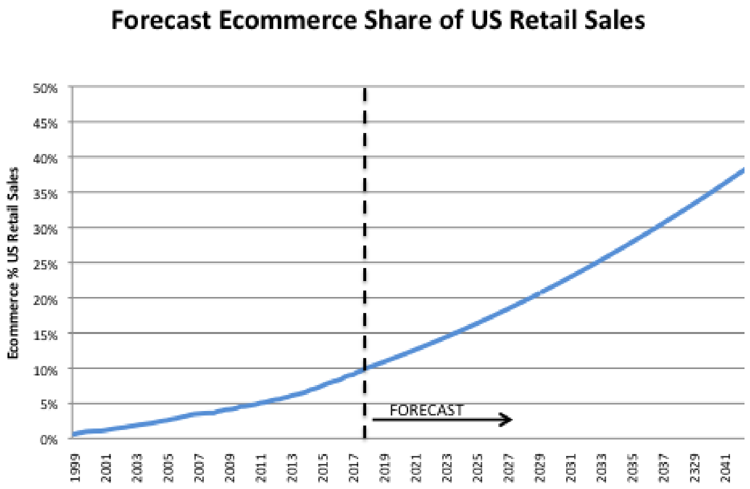
1. E-Commerce Research

- Key Trends:
  - Rapidly outpacing retail sales. 10% of retail market ($500bn)
  - Newer categories show greatest growth
  - Delivery time standards continually evolving (“Amazon Effect”)



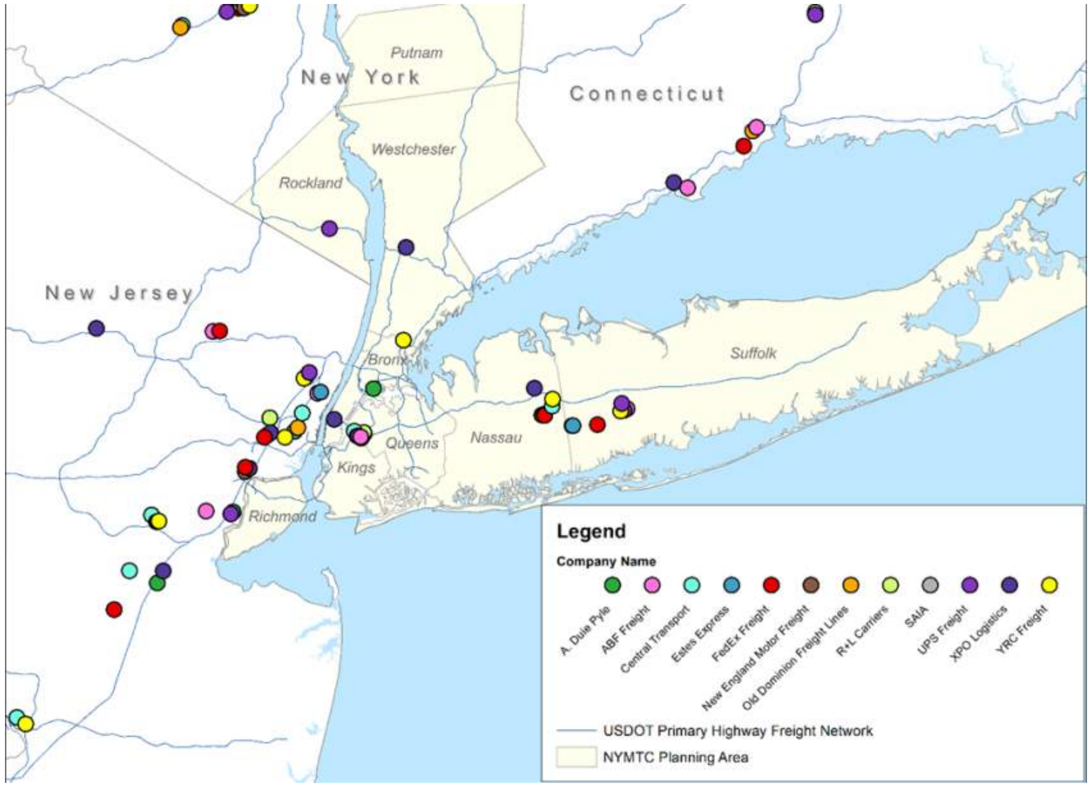
1. E-Commerce Research

- Effects on Supply Chain
    - Decentralization of distribution facilities (ex: Fresh Direct, Amazon, Jet.com)
    - Focus on fast and flexible skews toward truck, air



2. LTL Research

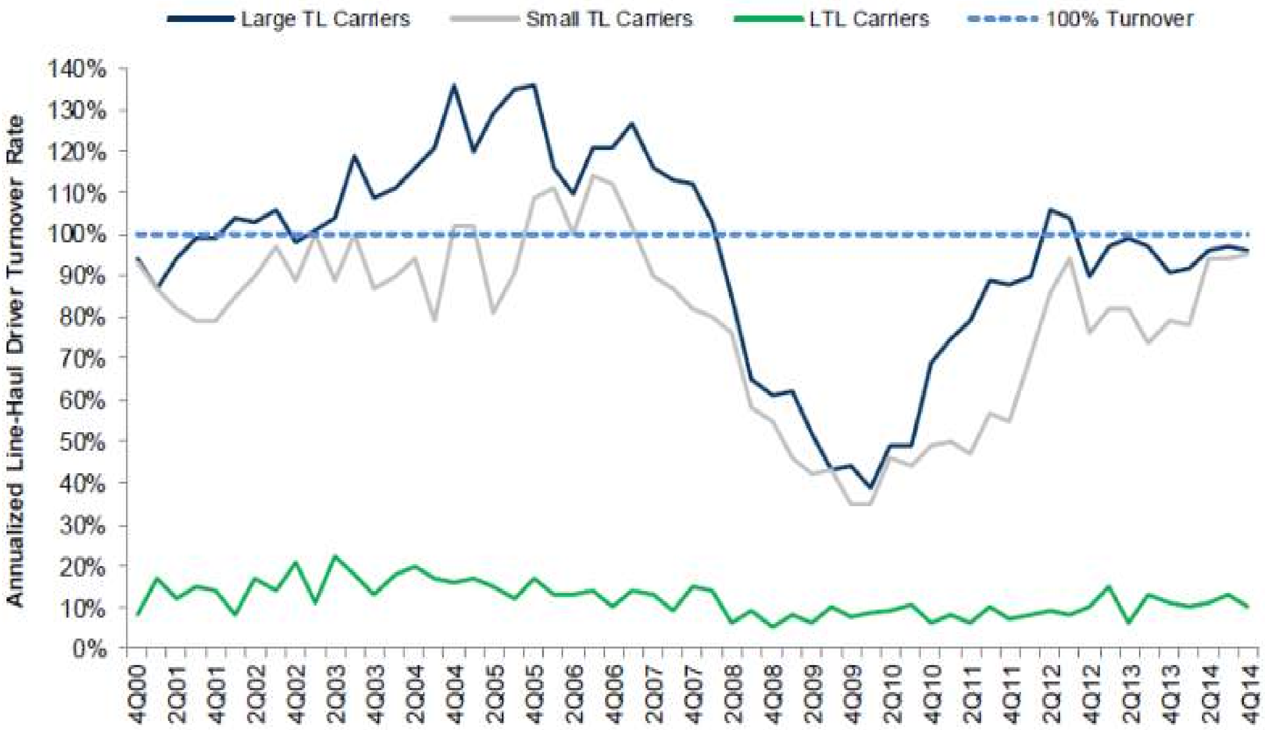
- Less-than-truckload (LTL) shipping (or less-than-load) is the transportation of relatively small freight
- Key Trends:
  - Industry is 10% larger than it was pre-Recession
  - Shipment size optimization
  - Mainly replaces truckload shipping
  - Growing role in home delivery
  - More attractive for young drivers than full load/long-haul



2. LTL Research

- Effects on Supply Chain:
  - Smaller shipments, greater frequency
  - More delivery trucks at peak hours due to intercity linehaul schedules
  - More terminals closer to customers
  - Superior driver pool compared to TL
- Approximate timing: Linked to E-commerce

Driver Retention in LTL Far Exceeds TL



3. Vehicle Automation Research – Trucks

- Key Trends
  - Level 1 highest commercially available. Level 2 & 3 in pre-commercial. Level 4 and 5 in R&D.
  - Federal and state regulations are critical.

Society of Engineers (SAE) Automation Levels		
0	No Automation	Zero autonomy; the driver performs all driving tasks.
1	Driver Assistance	Vehicle is controlled by the driver, but some driving assist features may be included in the vehicle design.
2	Partial Automation	Vehicle has combined automated functions, like acceleration and steering, but the driver must remain engaged with the driving task and monitor the environment at all times.
3	Conditional Automation	Driver is a necessity, but is not required to monitor the environment. The driver must be ready to take control of the vehicle at all times with notice.
4	High Automation	The vehicle is capable of performing all driving functions under certain conditions. The driver may have the option to control the vehicle.
5	Full Automation	The vehicle is capable of performing all driving functions under all conditions. The driver may have the option to control the vehicle.

3. Vehicle Automation Research - Trucks

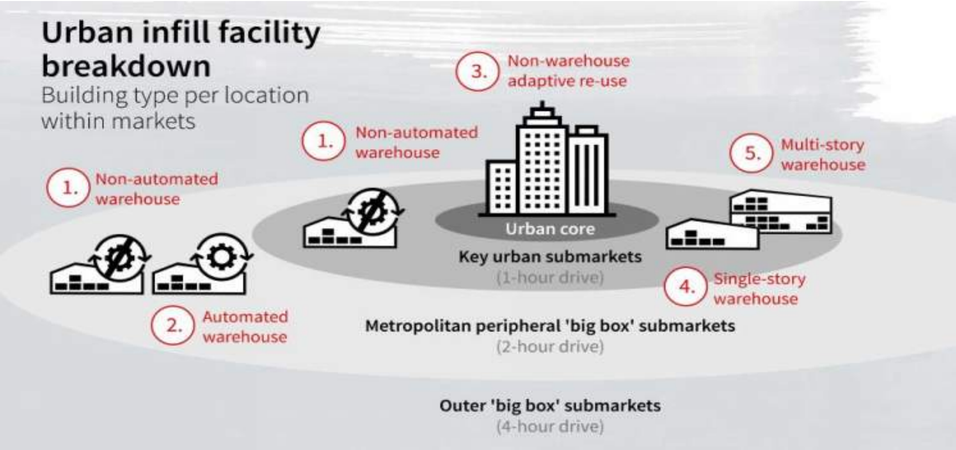
- Effects on Supply Chains & Timing:
  - Driver Shortage and Retention: possibly addresses some issues of hours-of-service, driver stress
  - Cost Savings: potentially reduce fuel consumption and increase labor productivity, particularly in long-haul trucking
  - Improved Safety: can reduce "human error," but many unknowns
  - Distribution Networks: initial impact to long-haul trucking; effects on facility location, etc., largely unknown
  - Obstacles to Adoption: significant technological, infrastructure, legal issues remain
  - Forecasts: International Transport Forum predicts Level 5 in 15% of heavy duty vehicle sales by 2035.

3. Vehicle Automation Research - Other

- Key Trends
  - Automation spreading throughout the freight sector
  - Delivery technologies
  - PTC and other rail tech
  - Marine terminals
  - Human factors and acceptability

4. Warehouse Design & Automation Research

- Key Trends
  - Multi-stage distribution: number of distribution centers (DCs) is increasing, average size is dropping
  - Multi-story facilities (urban infill) viable in some markets: New York fits the profile
  - Cross-docking will grow, but so too must product storage
  - Micro-warehousing



Source: RXR Realty, LBA Logistics

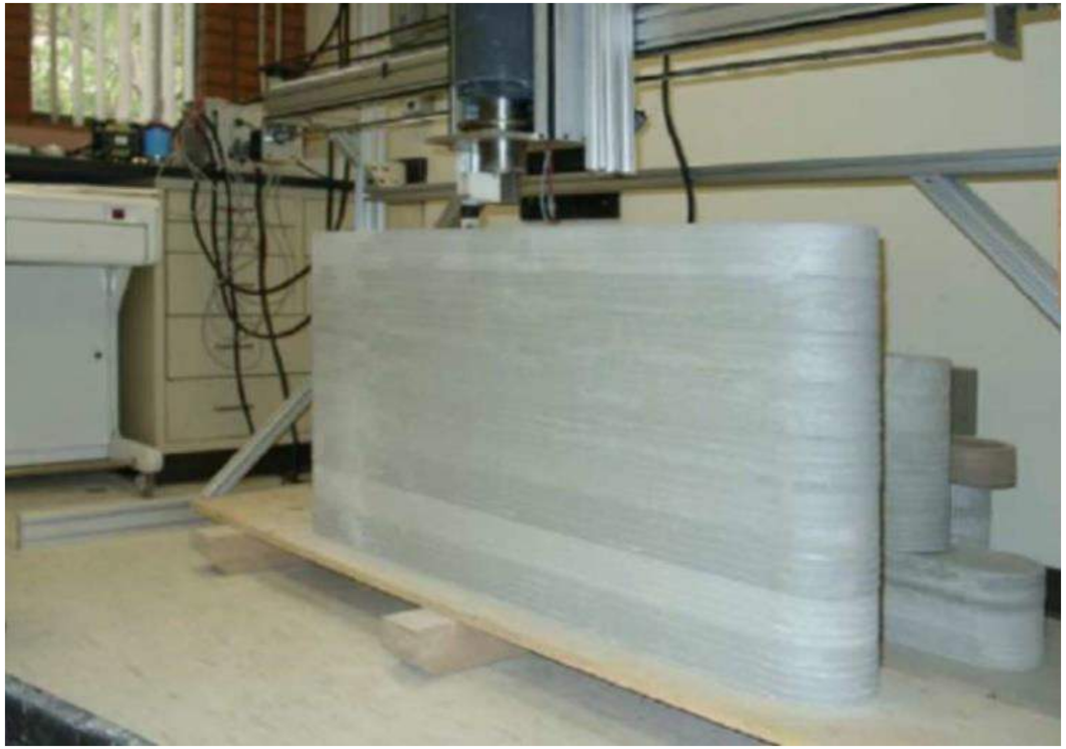
Source: JLL

4. Warehouse Design & Automation Research

- Effects on Supply Chains
  - Delivery service is overriding delivery cost because companies cannot compete at lower service levels
  - Automation and urban infill drive costs up near-term, may come down later
  - Urban locations becoming more competitive
  - Higher freight generation per acre (more productive facilities)
  - Freight generation in new locations (eastern PA)
  - Acute sensitivity to delivery speed and reliability
- Timing: now and near-term

5. Distributed Manufacturing Research

- Key Trends
  - 3D printing is a category of Additive Manufacturing (AM)
  - Allows mass customization, fast prototyping, minimization of waste, ability to manufacture complex designs
  - Making headway in consumer electronics, medical devices, aircraft components, footwear, toys, automotive, among others



Concrete Slab from a 3D Printer

Source: Elsevier Journal

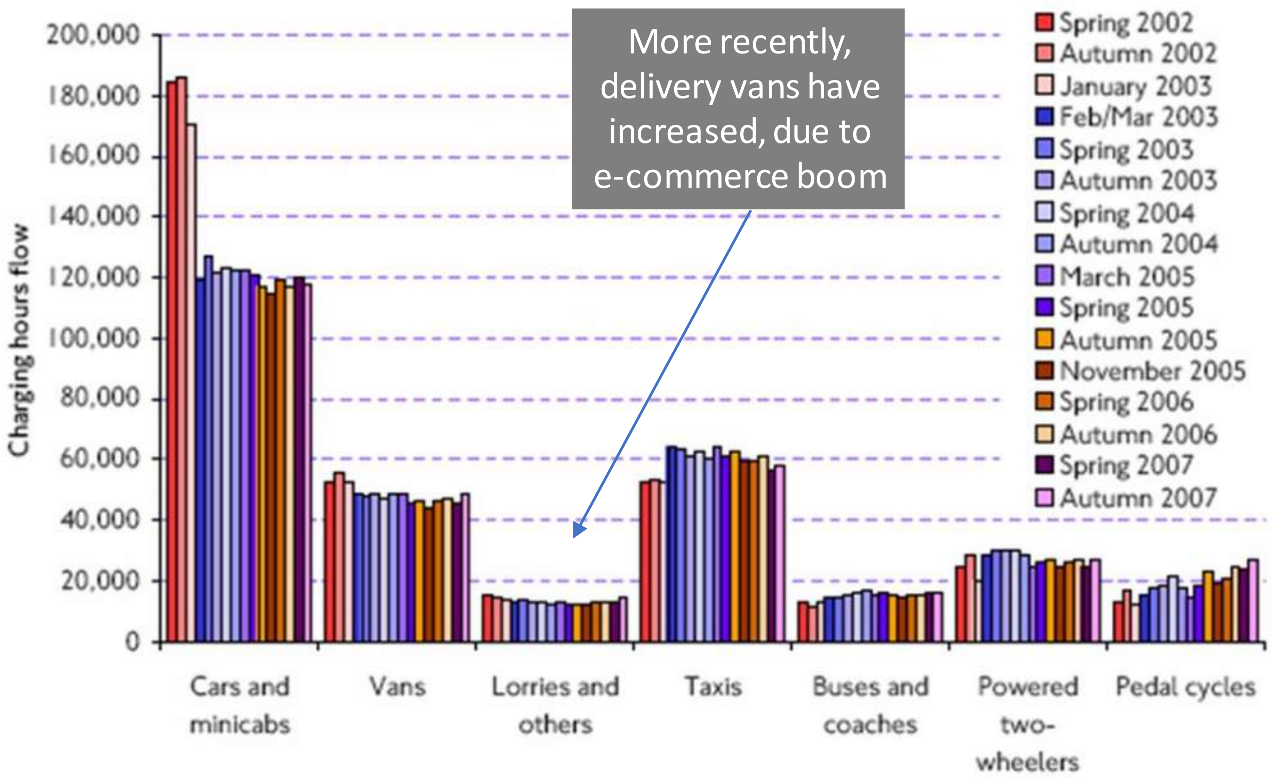
5. Distributed Manufacturing Research

- Effects on the Supply Chain
  - Changing production locations (printing can be done almost anywhere)
    - On-shored production of many consumer goods is possible, affecting import gateways
    - Could support specialized, small-scale local manufacturing in NYMTC planning area
  - Printing materials supply (often heavy materials), suitable for bulk transport by rail, water, etc.
- Timing
  - AM is projected to grow 15.2%/year through 2023
  - Trade factors could speed growth in near term

6. Congestion Pricing

- Biggest impact on passenger/auto trips, less on truck trip volume
- Increased cost of goods
- Could be problematic for small carriers if they cannot pass the cost on to customers

Figure 3.1 Traffic entering the central London charging zone (across all inbound roads), Charging hours, 07:00-18:00, 2002 to 2007.



7. Alternative Fuels

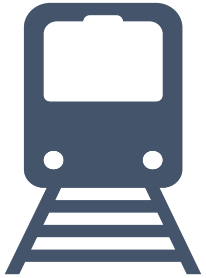
Truck

Fuels: NG, Propane, Electric

Deployment spurred by:

- Regulation (CARB, port requirements, etc.)
- Incentives (NYSERDA)
- Initiative, with large fleets leading

Timing: Slow in near term, change in diesel price (e.g., 2011-2013) could hasten adoption of alternative fuels



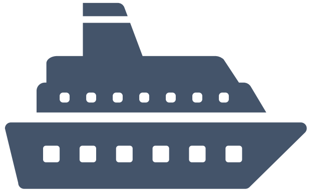
Rail Freight

Fuels: LNG and CNG

Deployment: A couple of shortlines, Class I opportunities begin with yard/switching locomotives

Timing: Slow in near term

7. Alternative Fuels

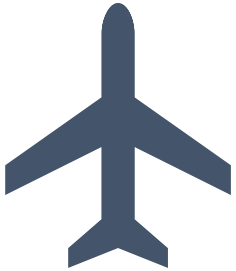


Marine

Fuels: LNG, potential for hydrogen, methanol longer-term

Deployment: Scrubbers being installed now to meet IMO 2020. Fuel conversion is limited, lots of practical barriers

Timing: Mid-to-long-term



Air

Fuels: “drop-in” blends

Deployment: 100,000 flights in 2017

Timing: Int’l Air Transport Assn (IATA) Goals:
1 million flights using sustainable blends by 2020;
halve CO_2 emissions by 2050

Conclusions: Impacts on Regional Freight Plan Recommendations

Planning Initiatives

- Anticipate longer-term effects of trends
- Emphasis on strategies that improve truck safety, delivery and last-mile issues, and industrial land use
- Technological innovation suggests potential partnerships with tech firms who are expanding their presence in the region

Project Planning and/or Environmental Reviews

- Special consideration to how trends impact modal utilization, industry location decisions, and operating characteristics.
- Consider highway, rail, marine technological advances and potential impacts on modal balance

Conclusions: Impacts on Regional Freight Plan Recommendations

Programmed Improvement Projects

- Trends do not change need for safety and preservation projects
- Economic development and transportation access projects can leverage E-commerce, additive manufacturing (AM), and support/drive growth in those sectors here

Policies and Programs

- Automation can facilitate off-hours delivery, freight village, and other policies in the Plan
- Dredging and rail access programs can support need for AM raw materials transport
- Urban logistics and freight village policies can be adapted to meet E-commerce, LTL, AM, and automated delivery advancements
- E-commerce and DC trends help overcome high cost of industrial development in this region
- AM could lead to new market segment for industrial real estate, and support economic development strategies

Attachment B

NYMTC Regional Freight Plan 2018-2045

Task 6: Potential Impacts of Trends on the Feasibility of Improvements and Solutions

draft

memorandum

February 2019

Table of Contents

List of Tables and Figures

1.0 Introduction

The companies and agencies that carry, send, receive, or manage the movement of goods within the NYMTC planning area and around the world are developing and deploying new technologies and new processes to improve the efficiency of goods movement, reduce costs, comply with regulatory or customer-driven demands, and/or improve profitability. New business models are being developed, and will likely continue to be developed, in order to adapt to and capitalize upon opportunities that technological developments create. The extent to which such technologies and processes are adopted and implemented, and the potential effects on goods movement demand and travel patterns within the NYMTC planning area specifically, can be difficult to gauge. Available freight data and forecasts assume a “business as usual” future, where the relative costs and performance of each transportation mode are approximately the same, and use the same decision-making criteria as they do today.

In Sections 2, 3, 4, 5, and 6, this memorandum identifies and describes recent and future trends and issues that are impacting, or could potentially impact, drivers of freight demand and logistics patterns. Through the analysis completed under the Task 4 Needs Assessment, many of those issues have already been identified, and include the effects of E-commerce on the retail supply chain and reverse logistics, truck loading (including less-than-truckload shipments), autonomous trucks and platoons, warehouse design and automation and its influence on site location, and distributed manufacturing (i.e., 3D printing). For each trend, the magnitude, approximate timing, and measures that affect freight demand and cost, are examined, to the extent possible with available data and literature.

Trends that increase or alter how goods move could result in a larger volume of freight moving in the region than the Regional Freight Plan forecast suggests, or greater concentration in certain areas. Changes in transportation cost (due to labor, regulatory, economic, technological or other factors) could induce additional freight travel demand if the cost trends downward, or limit growth in freight demand if costs increase significantly. Section 7 discusses, qualitatively, the uneven application of transportation cost impacts across commodity groups and modes, and potential effects on economic growth and modal shares.

Understanding how trends could impact demand and cost across modes, it may become evident that certain types of improvements and solutions in the Regional Freight Plan could achieve higher or lower priority compared to other improvements and solutions. For example, if the trends are likely to increase trucking costs relative to rail for shipments where rail can compete, we could infer that more freight will move by rail than projected in the Regional Freight Plan Needs Assessment. This finding would suggest that studies and projects that aim to increase rail freight capacity or improve rail access may become higher-priority investments.

The timing of some of the trends and their impacts on the supply chain and Regional Freight Plan recommendations are described as near-term (within the next 5 years), medium-term (6-10 years), or long-term (10-25 years)

2.0 E-commerce

2.1 Trends

E-commerce shipments are defined by the US Census Department as online orders for manufactured products where price and terms of sale are negotiated over the Internet, Extranet, Electronic Data Interchange (EDI) network, e-mail, or other online system. US e-commerce sales have been rapidly expanding since the late 1990s, rising from $4.5 billion in the fourth quarter of 1999 to $$130.9 billion in the third quarter of 2018, per data from the US Census. Growth in online sales has widely outpaced overall retail sales growth. Between the fourth quarter of 1999 and the third quarter of 2018, quarterly e-commerce sales increased by an average of 18.9 percent year-over-year, compared to a pace of just 3.4 percent for total retail sales.[1] As a result, e-commerce now accounts for nearly 10 percent of total US retail sales, compared to less than one percent in 1999. Moreover, recent years have not pointed to a slowdown in e-commerce's penetration of the retail market. On the contrary, the e-commerce portion of overall retail sales increased by nearly one full percentage during each of the last three years for which data is available.

Non-store retailers account for the vast majority of e-commerce retail sales, comprising 85.9 percent of total sales in 2016. Motor vehicles and parts dealers are the second largest category, accounting for another 8.2 percent of online purchases. However, as e-commerce has more broadly infiltrated the overall economy in recent years, the market segments with the largest growth in sales have been the smaller categories of clothing, food and beverage, and furniture stores. Between 2012-2016, annual growth in these three segments averaged 25.1 percent, 24.5 percent and 22.1 percent, respectively, far outpacing overall e-commerce sales (see Figure 2.1). These newer, less-established e-commerce categories have perhaps the greatest potential for growth going forward.

In the NYMTC planning area, NYCDOT's 2017 Citywide Mobility Survey indicated that 41 percent of New Yorkers receive home delivery at least a few times a week. This is partially the result of Amazon's rapid expansion in the area. According to the 2018 NYU Rudin Center "Online Consumption and Mobility Practices: Crossing Views from Paris and NYC", 37 percent of Manhattan residents use Amazon Prime.

2.1.1 D2C

The rise in e-commerce and direct-to-consumer (D2C) retail is having significant repercussions on product distribution and delivery, with many more shipments going directly to individual residences, rather than brick-and-mortar storefronts. Many retailers are using large package delivery companies such as UPS, FedEx, and USPS to handle these deliveries, significantly altering the business model for such companies. For example, D2C shipments now represent more than 50 percent of UPS's total domestic volumes. According the company's annual report, this portion of shipments expanded by 9.3 percent in 2017, adding to a nearly nine percent increase the previous year. The company directly credited e-commerce for the growth, which included both air and ground shipments. Also notable, B2B (business-to-business) shipments decreased slightly in 2017, following a flat performance in 2016. This

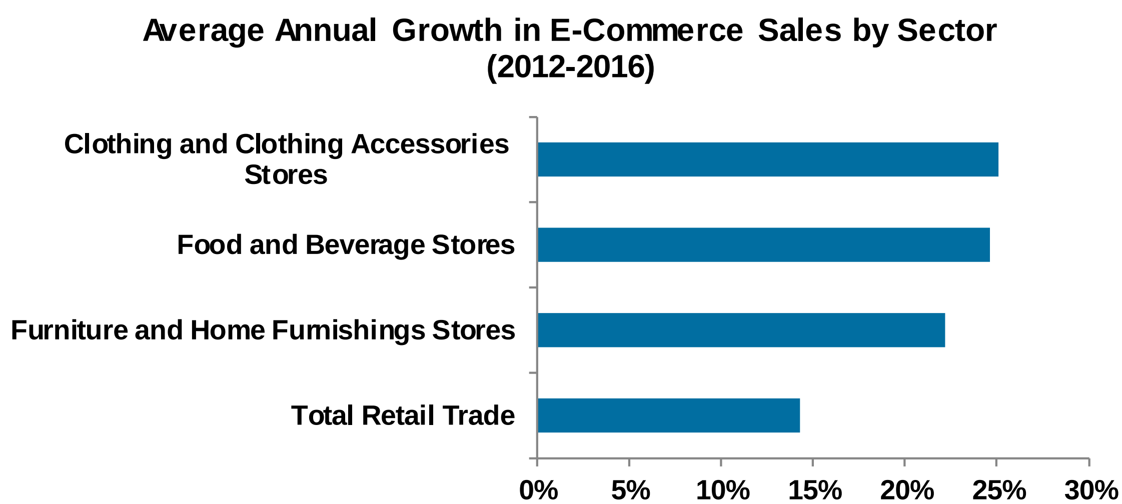
[1] https://www.census.gov/programs-surveys/e-stats.html

(Footnote continued on next page...)

is due in part to increased use of digitization, as businesses are increasingly using electronic documents in the place of hard copy paper.[2]

The shift toward D2C delivery has forced many retailers to focus more on last-mile logistics, which is generally considered to be the most complex and costly portion of the delivery process. While many continue to outsource this service to one of the Big Three delivery companies (UPS, FedEx, and USPS), some are opting for their own delivery service. For example, in 2017, Wal-Mart acquired Parcel, a same-day and last-mile delivery company specializing in perishable and non-perishable delivery to customers in New York. Others are utilizing start-ups like Deliv, which provides crowd-sourced same-day delivery for malls and retailers like Macy's and Best Buy. There are also hybrids, such as DHL's new Parcel Metro, which offers a mix of delivery vendors and crowd-sourced drivers in an effort to maximize flexibility and capacity. The end result of these developments is that the rise in e-commerce has produced in a significant number of new participants in the distribution network, as well as new vehicles on the road.

Figure 2.1 Fastest Growing E-Commerce Categories



Source: US Census Bureau, Annual Retail Trade Survey

2.1.2 Delivery Time Standards and the "Amazon Effect"

Amazon is the undisputed leader in terms of US e-commerce sales. One of the first large companies to sell products over the Internet in the mid-1990s, Amazon is widely credited with popularizing online shopping. This single company will account for an estimated 48 percent of total US digital sales in 2018, according to eMarketer. eBay was listed as a distant second, at 7.2 percent, followed by Wal-Mart at 4.0 percent. Equally notable, Amazon's rising market penetration has not slowed in recent years, as its market share was estimated by eMarketer at 43.5 percent in 2017 and 38.3 percent in 2016.[3] Such

[2] http://www.investors.ups.com/financials/annual-reports

[3] https://retail.emarketer.com/article/emarketer-releases-first-forecast-of-top-E-commerce-retailers/

growth has enabled Amazon to amass nearly five percent of total US retail sales annually, with further gains widely expected.

The 800-pound gorilla in e-commerce, Amazon continues to dramatically impact consumer expectations regarding product delivery standards. In 2005, the company started Amazon Prime, providing free two-day shipping on certain products to Prime members for an annual fee. More recently, Prime Now offers free same-day delivery in major metro markets and faster and/or tailored delivery for select high-volume goods for an additional fee. Given Amazon's significant market presence, other major retailers have had little choice but to follow suit, offering a combination of free and/or faster delivery. For instance, Target acquired online same-day delivery platform Shipt late last year with the goal of providing same-day delivery for all major product categories in all major markets by the end of 2019. This is one of many examples of a trend that has become pervasive. According to a 2018 Deloitte survey, 62 percent of respondents defined "fast shipping" as two days or less, up from 54 percent in 2017.[4]

2.2 Expected Effects on the Supply Chain

2.2.1 Consumable Goods and Delivery Time Standards

While durable goods continue to lead e-commerce sales, many consumable goods, most notably groceries, are experiencing significant growth – a trend that is expected to continue going forward. According to Unata's 2018 Grocery E-commerce Forecast, 36 percent of people surveyed planned to order groceries online in 2018, up from the 22 percent who reported grocery shopping online in 2017, a growth rate of 64 percent. Amazon's purchase of Whole Foods in 2017 is undoubtedly contributing to the expansion. Wal-Mart has also been aggressive in the online grocery space, announcing plans in early 2018 to expand its online grocery delivery service to 100 metropolitan areas by year's end. At the same time, Kroger is in the testing stage for the first fully self-driving grocery deliver service with no human being in the vehicle.

New York's online grocery market is more established in comparison to the US as a whole, due in part to the arrival of Fresh Direct in the late 1990s. This privately held company is estimated to control over 50 percent of the New York area online grocery market. Nonetheless, there is ample opportunity for growth. The success of Fresh Direct, which has reportedly seen sales double in the past six years and recently opened a massive new facility in the Bronx, is drawing significant competition. Not just from established players such as Peapod and Amazon Fresh, but also relative newcomers. Wal-Mart's Jet.com in particular is making a major push into the region, offering same-day and next day delivery service from its brand-new fulfillment center in the Bronx. Meanwhile, Instacart, a company that contracts with individuals to use their own cars to deliver groceries to customers, is also growing rapidly in the area.

2.2.2 Production/Distribution Networks:

The rapid growth in the D2C market combined with faster delivery standards is having significant repercussions on warehouse location decisions. There is a notable shift away from the practice of using a small number of enormous facilities located at a considerable distance from the urban areas they serve, toward using more numerous, smaller industrial spaces located closer to the end consumer. For the NYMTC planning area, this has resulted in a number of new facilities in the outer boroughs of New

4 https://www2.deloitte.com/us/en/pages/about-deloitte/articles/press-releases/deloitte-study-holiday-shoppers-hooked-on-fast-and-free-shipping.html

York. As mentioned previously, Fresh Direct and Jet.com both opened new fulfillment centers in the Bronx in 2018. Similarly, Amazon opened a new fulfillment center in Staten Island, its first in the area. Amazon had previously served the New York market via facilities in New Jersey and Pennsylvania. One result of this trend is greater stress and congestion on local roadways, both from trucks and small vehicles.

Meanwhile, altering standard delivery times and costs are not the only ways Amazon is making its mark on the logistics industry. USPS, UPS and FedEx currently deliver an estimated 90 percent of Amazon's packages, with USPS alone reportedly handling 40 percent of all US Amazon orders. However, in recent years Amazon has taken several notable steps toward gaining ever-greater control over its own logistics network. In 2016, Amazon entered into the air cargo space, leasing 40 jets from ABX for a new service operating out of the Lehigh Valley International Airport, among other airports. Also in the same year, Amazon registered with Federal Motor Carrier Safety Administration as a freight broker, and with the Federal Maritime Commission as a non-vessel-operating common carrier (NVOCC). Additionally, the company has been assembling its own fleet of delivery vans operated by independent contractors. While Amazon has maintained such services are only in place to supplement third-party capacity, given its significant impact on the retail market, its dealings in the distribution market are expected to have major repercussions for overall logistics operations and pricing.

2.2.3 Modal Utilization and Routing

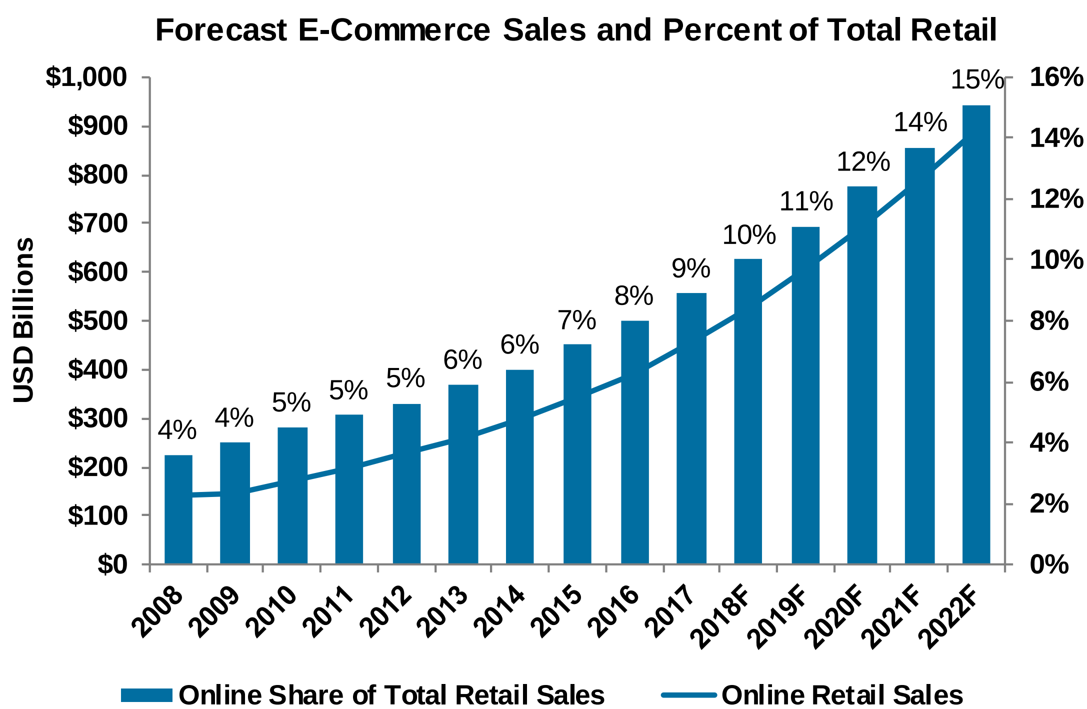
The ongoing expansion of e-commerce sales is forcing retail and logistics providers to rethink pricing and delivery-mode strategies. For companies such as UPS and FedEx, home deliveries are generally less profitable than business-to-business deliveries, which often consist of a larger number of parcels per stop. Further exacerbating costs is the fact that consumers are increasingly purchasing bulk items such as furniture and appliances online. In response to these cost increases, both companies have repeatedly raised rates on large and oversize packages, while at the same time reducing the dimensions of packages that qualify for additional surcharges. The goal is not only to maximize profitability, but also to discourage customers from using their small-package network for items that should be moved through their freight networks. Meanwhile, these rising surcharges and the shift to delivery pricing based on dimensions rather than weight is likely one reason Amazon has entered the air cargo space. Shipping lightweight packages via their own leased airplanes allows Amazon to avoid the escalating fees on large and oversize ground packages. On a related topic, as a result of the overall rise in E-commerce sales and the corresponding change in commonly shipped commodities, most cargo flights are now maxing out on volume rather than weight.

Another trend that has emerged as a result of the focus on low-cost, expedited shipping is the use of crowd-sourcing for last mile deliveries. Similar to Uber, this involves technology-enabled companies dispatching individual contractors who use their own personal vehicles for deliveries. As of now, this method is often used for meal and grocery delivery, as well as medical supplies, but a handful of successful startups, include Deliv, Instacart and UberRush, have moved into other areas of retail. Additionally, Amazon has its own crowd sourced delivery service called Amazon Flex. While such systems allow for fast, localized delivery with limited overhead to the company, there are costs to the overall transportation system. These include increased congestion, uncounted trips, unregulated vehicles, and reduced coordination and consolidation of delivery services. Moreover, curb space for these deliveries is limited and double-parked trucks are recognized for their impact on local traffic.

2.3 Approximate Timing of the Effects

E-commerce as a percentage of overall retail sales has been on an upward trajectory since the late 1990s. Technological advances continue to support online sales growth by allowing consumers greater access to product information, quick and easy price comparisons, and faster, cheaper, personalized delivery options. Moreover, as same-day delivery and free shipping on returns become more commonplace, the allure of brick-and-mortar stores diminishes further. Thus there is little reason to expect a slowdown in the growth of online sales market penetration in the next five years. Indeed eMarketer is forecasting a continuation of robust growth, with online sales expected to account for more than 15 percent of total retail sales by 2022 (see Figure 2.2) While there is no doubt a saturation point in terms of e-commerce as a percent of overall retails sales, we are not likely to reach it soon.

Figure 2.2 E-Commerce Retail Market Growth – Trend and Short-term Forecast



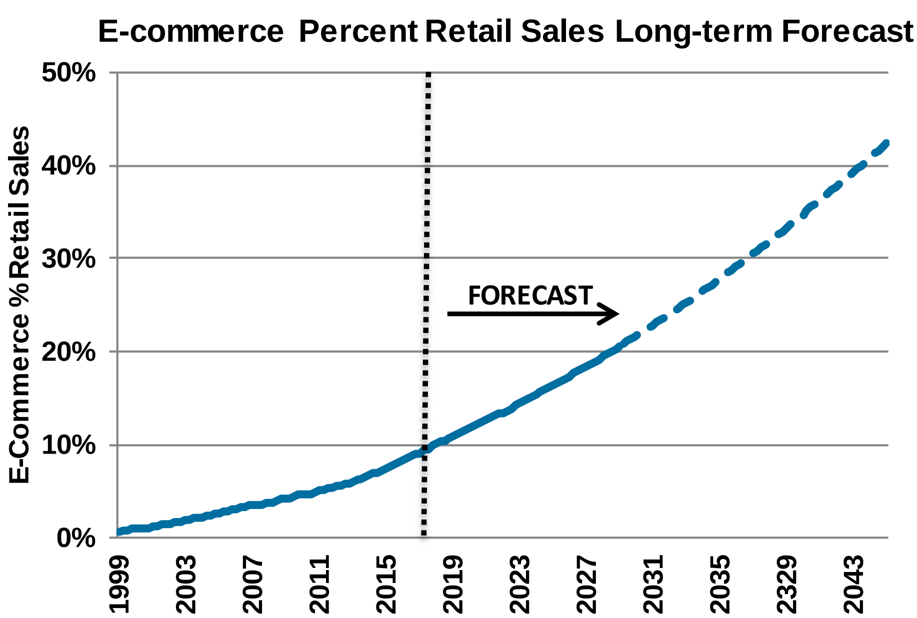
Source: eMarketer, CBRE Research

The continued rise in e-commerce sales has significant implications over warehouse demand. The D2C market translates into fewer goods inventories in retail stores and greater volumes of goods on warehouse racks for delivery. CBRE Research estimates that for every $1 billion increase in E-commerce sales, an estimated 1.25 million square feet of warehouse space is needed to keep up with demand. Utilizing eMarketer's online sales forecast, CBRE estimates that e-commerce generated warehouse demand could grow, nationally, by an additional 191 million square feet from 2018 to 2020.[5] That additional warehousing could generate 115,000 additional daily truck trips in the United States.[6]

Readily available industry forecasts on E-commerce retail sales are limited to short-term estimates such as the one depicted in Figure 2.2. In an effort to provide a longer-term view, the Team undertook its own economic analysis of the time path for e-commerce as a portion of retail sales. Using a constant growth rate based on historical performance would imply a 3.7 percent quarterly pace, lifting e-commerce's share of total US retail sales to 100 percent by the middle of 2034 – an unlikely scenario. This is a far too rapid advance and would constitute a drastic shift in the way sales retail sales are conducted in the US. Theoretically, the share of e-commerce sales should grow swiftly and even accelerate in the future, as increasing numbers of households are connected to the Internet, while shoppers who do not use Internet shopping age and drop out of the shopping population. Indeed, it could be argued that e-commerce is more or less a "normal" shopping avenue for new entrants into the shopping population. Nonetheless, it seems implausible that all retail sales will be conducted electronically by 2034.

Against this backdrop and utilizing historical e-commerce data from the Census Department, the Team developed a number of time series models to predict plausible e-commerce shares through 2045.[7] The most reasonable result, shown in Figure 2.3, is with use of a regression of e-commerce share on time. This approach generates a forecasted e-commerce share of just over 40 percent in 2045.

Figure 2.3 E-Commerce Retail Market Growth – Long-term Forecast



Source: US Census Department, Cheng Solutions LLC

[5] US Market Flash Warehouse Demand to Grow with Rising E-commerce Sales (CBRE)

[6] Estimated using the Institute of Transportation Engineers standard warehousing truck trip generation rate of 0.6 trucks per 1,000 square feet. It is important to note that the development of more trip-intensive cold storage and use of less-than-truckload for delivery could result in a larger number of trips.

[7] Noted: Rapidly developing changes in the e-commerce field make a long-term forecast for this sector highly unpredictable.

While it seems clear that growth in e-commerce will continue to outpace overall retail sales for some time, the future of product delivery, particularly last-mile logistics, is far from certain. One possibility that has received considerable attention is drone delivery. Multiple groups are in various testing stages, including smaller companies like Workhorse and Matternet, as well as larger corporations like Google and Wal-Mart. Additionally, Amazon has patented mobile drone delivery hubs that could travel along railroads, seaways and roads. The federal government has also gotten involved via the UAS Integration Pilot Program, which encourages local governments to partner with private companies. The goal is to promote innovation, while at the same time helping the Department of Transportation and Federal Aviation Administration craft new regulatory guidelines for drone usage. Nonetheless, while drone technology is fairly advanced, the actual feasibility of drone delivery is far from certain. In addition to the numerous safety and security concerns, there are multiple factors related to economics, weather, and urban landscape that limit the practically of a widespread drone delivery operations in a major metropolitan area such as New York.

3.0 Less-Than-Truckload (LTL)

3.1 Trends

3.1.1 Resurgent sector

Less-Than-Truckload (LTL) motor carriage is a $35 billion sector of the $700 billion U.S. trucking industry.[8] Roughly 10 percent larger than it was coming out of the Great Recession, the sector has good growth prospects due to current market factors.

LTL trucking is a terminal operation handling smaller shipments. LTL shipments are larger than those moved by parcel carriers but smaller than shipments by the truckload fleets that dominate the trucking industry: parcel shipments average about 5 pounds, LTL shipments about 1,300 pounds, and truckloads well over 10,000 pounds. Trucking is most efficient when trucks are full; maintaining full loads with small shipments requires consolidation through terminal networks. LTL "city" drivers fill their trucks by serving many local customers shipping to many places. They return to terminals, where shipments headed to the same destinations are consolidated into full loads. These loads are taken by linehaul or "road" drivers to terminals in the destination cities, where they are deconsolidated for delivery to customers in the local area.

Prior to deregulation of motor carriage in 1980, most of the US trucking industry ran in LTL networks and most of it was unionized. Deregulation brought major retrenchment, fundamentally because it freed truckload operations to flourish. Full truckload (TL) fleets ran from one shipper to one receiver without terminals and with non-union drivers. This offered faster, more reliable service at much lower cost, and it became the dominant business model in the industry. LTL gradually shrank to a niche business focused especially on next day and second day regional service, employing mostly non-union labor. The larger LTL carriers have a presence in multiple regions, and two of the largest are owned by the two main, commercial parcel delivery companies: FedEx Freight and UPS Freight. Today, the LTL niche is ripe for

[8] SJ Consulting for LTL market size, quoted in Journal of Commerce, 5/18. American Trucking Association is the source for size of total industry.

expansion. One reason is tight capacity in the truckload sector brought on by a shortage of drivers (explored further below); a second reason is change in the retail market.

An important dynamic following deregulation was that major retailers led by Walmart took control of their inbound supply from manufacturers. Truckload consolidation was introduced for goods moving into the retailers' Regional Distribution Centers (RDCs), which were outside urban areas and executed store delivery with private or dedicated fleets moving full truckloads to one or two outlets. This method eliminated most LTL activity; LTL carriers continued to serve manufacturers for industrial shipments, but were cut out of the prime retail channels. E-commerce has now disrupted this arrangement by creating a new D2C retail channel driven by small orders and shipments, which are difficult to consolidate because accelerating delivery requirements leave too little time. Store-based retailers have been forced to fragment portions of their supply chain to compete with D2C, contributing to growth in parcel shipping and to resurgence in the LTL sector. Moreover, the LTL business base in manufacturing is positively affected as well, through small product shipments to fulfillment centers and shipments direct to consumers who order on-line. An illustration of this appears in Figure 3.1, which is a marketing flyer sent to consumers for the Black Friday shopping day of the Thanksgiving 2018 holiday weekend. The flyer is noteworthy for several points:

- This is joint marketing by Amazon and the consumer goods manufacturer Procter and Gamble.

- The goods advertised are everyday household items such as detergent, paper towels, diapers and toothpaste. They are not gift items, nor are they brands currently carried by Amazon's Whole Foods grocery stores. Thus the purpose of the advertising is not to attract holiday shopping, but rather to shift consumer preferences from stores to the on-line channel.

- The goods include bulky and heavy items. Whether they are shipped to consumers from Amazon fulfillment centers or from manufacturer DCs, they are big[9] for parcels and in larger quantities could favor LTL. UPS and FedEx in fact could adjust their pricing to favor their parcel or LTL divisions according to the volumes and patterns in local markets.

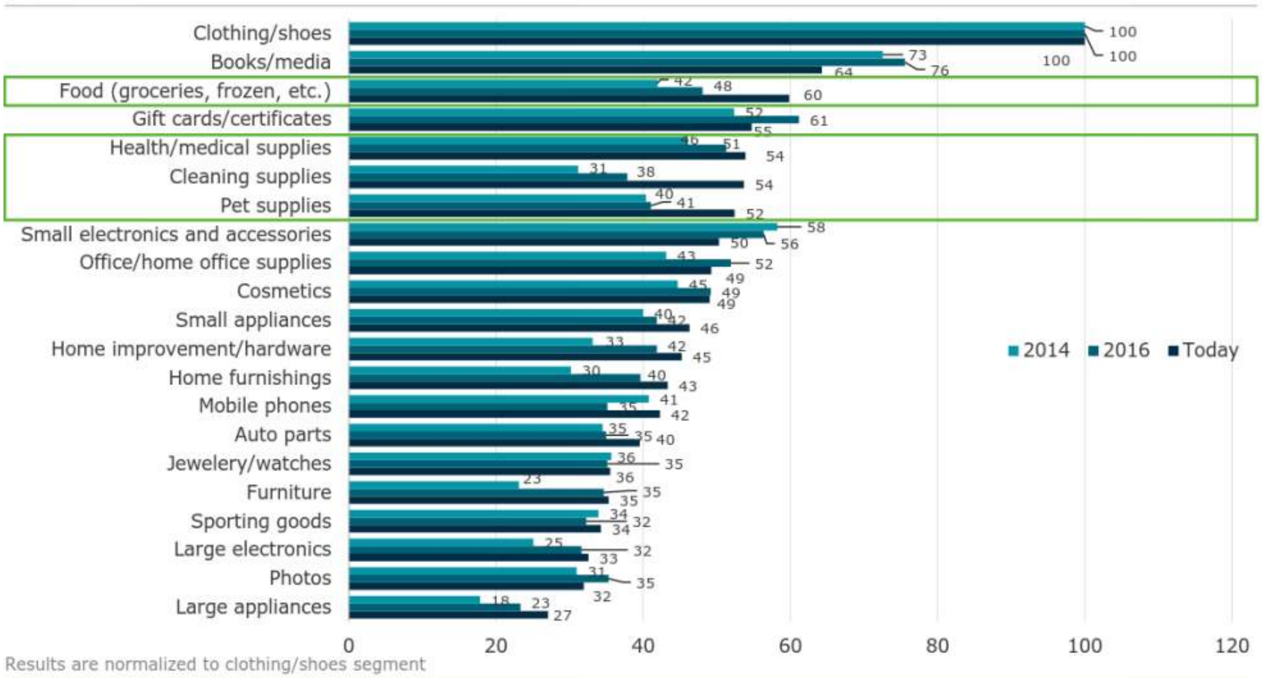
[9] Manufacturers of products like detergent in fact are being encouraged by Amazon and others to change product formulas and packaging for more efficient shipping. See for example the Associated Press piece "Lighter Load: Laundry Detergents Shrink for Amazon", reported in The New York Times, 12/27/18.

Figure 3.1 Joint Marketing Flyer

3.1.2 Optimizing shipment size

D2C purchases are small orders for small shipments, because they are placed by individual consumers instead of in aggregate by stores. As previously noted, this leads to fragmentation in the supply chain and fewer truckload quantities. In addition, Amazon and others have been cultivating a broader array of products purchased through the home delivery channel, as Figure 3.2 depicts. The list is increasingly long and diverse; it includes heavier goods such as pet food and the detergents discussed above, and it extends to furniture and home goods offered by e-tailers such as Wayfair. While the product array suggests even more small shipments, it suggests opportunity for consolidation, too. Consolidation arises most readily for goods inbound to fulfillment centers - facilities that today are locating more often inside metropolitan areas (see the section on Warehouse Design and Automation, below). Consolidation also can occur at the household and neighborhood level: the higher the share of household purchases accomplished on-line, the larger the quantity of goods shipped directly to homes. Delivery lockers and in-store pick-up are further means by which shipments can be combined.

Figure 3.2 Products Purchased for Home Delivery



Source: Alix Partners; national survey conducted 11/17 for products purchased in previous 12 months

These dynamics imply that portions of demand will not be met by the service offerings of parcel carriers. LTL is the next step up in shipment size, consolidation and carrying capacity of delivery vehicles. Moreover, the regional carriers leading the LTL industry have perfected next day delivery networks that can satisfy the stringent service requirements of e-commerce. They are supplemented by value-added services like pool distribution that help reduce supply chain costs. Even so, two points should be remembered:

- LTL carriers typically avoid the smallest shipments as unprofitable in their operations. They will not automatically embrace e-commerce traffic: the right combination of size, price and delivery density is required, and this will vary by carrier and location in the NYMTC market area. Fulfillment center inbound traffic will fit the profit profile better than home delivery, but both should grow.

- Home delivery is expensive, and "free" delivery means it is subsidized for market share gains. Higher market share brings the volume needed to construct economies from consolidation and delivery density, yet not all volume is equally efficient. Retailers and carriers alike will continually seek delivery cost reductions and innovations where service commitments allow.

3.1.3 Role in home delivery

Diversity of products and sources in the D2C channel, coupled with lean inventory and fast delivery imply that fulfillment centers shipping directly to consumers will receive more inbound shipments by LTL because all of those factors work together to trim the opportunities for truckload consolidation. LTL carriers have decades of experience with industrial style deliveries to warehouses; fulfillment center business should be attractive to them and expand. Home delivery is a different matter: volumes are smaller and more scattered, residences are not designed for truck deliveries and neither are local streets. Nevertheless, as products in the channel become heavier, bulkier, and more numerous, LTL will grow in the delivery mix. A street of high-rise condominiums can consume more than a parcel van of groceries; manufacturers of large household goods may be better served by an LTL terminal than a fulfillment center. “White glove” home delivery, assembly and installation services for products like appliances are offered by some LTL carriers in the NYMTC region now.

A second consideration is the similarity of parcel and LTL operations, which both employ terminal networks and perform delivery across multiple stops. The logistical character of shipments for home delivery is well suited to parcel carriers at current volumes. If parcel capabilities eventually are exceeded, LTL is the most likely alternative, because it has capacity for larger shipments while retaining the terminals and multi-stop operations that fit the logistics profile. By contrast, a TL operation may make several stops, but certainly not the dozen or dozens that LTL and parcel fleets routinely perform.

3.1.4 Career path for youth

The trucking industry has a chronic challenge in its ability to attract drivers, particularly young ones. There are many reasons for this, but a key obstacle is age minimums. A driver must be 21 years old to qualify for a Commercial Driver’s License, and insurance companies will not offer coverage below 25. By the age of 25, most career-minded young people will have found a different industry to join.

LTL carriers offer employment at a younger age with a genuine career path. Teenagers can begin as part-time or full-time dock hands in the terminal, then move up to driving or supervision as they gain education and experience. Driving positions can be city delivery or intercity linehaul. City jobs allow drivers to be home every night; intercity jobs allow road drivers to be home every other night, and sometimes more often. Both options are better for development of family lives than the extended absences required in some parts of the truckload sector.

3.2 Impacts on the Supply Chain

3.2.1 Truck size, delivery frequency, cost

Size: The typical equipment in LTL trucking is a 28’ pup trailer, which can be used alone for city delivery or in pairs for intercity linehaul. The trailer is hitched to a city cab or a road tractor. Carriers also use 40’ box trucks for city delivery, dry van trailers up to 53’ for linehaul and city work, and a variety of other sizes depending on locations, volumes, restrictions and management preferences. An example appears in Figure 3.3 for an LTL carrier active in the NYMTC region. Companies strive to match the equipment to the operation in order to maximize efficiency and control costs.

The significance of LTL growth in the NYMTC region is a matter of what the growth replaces. Where it supplants parcel delivery, the equipment will be larger; where it supplants truckload shipping, the equipment will be no larger and should be smaller overall. LTL equipment size should be stable in the years ahead. One possible exception is the potential for federal regulation allowing 33’ pup trailers. This configuration has been advocated by the LTL industry, and was one of the principal types examined in the inconclusive federal Truck Size and Weight Study of 2015.

Figure 3.3 City Cab with Trailer

Frequency: Growth in LTL shipping comes chiefly at the expense of truckload shipping. Because the total demand for goods isn't falling, and the requirement for faster time to market is not abating, then more LTL shipping entails more individual truck deliveries occurring more often. This adds to the pressure on highway and local road capacity, and on the capacity of loading docks and street parking to absorb greater numbers of trucks.

Cost: LTL is a terminal operation facilitating consolidation of shipments. This handling process, plus the expense of dock hands, city as well as road tractors, and the terminals themselves add substantially to cost. For comparison, a truckload shipment involves one laborer, one pickup, one delivery, and one truck; LTL shipments involve several of each. Growth in LTL that replaces truckload shipping inevitably brings higher costs for delivery of goods to the NYMTC region. Companies pay the cost when the market demands and will support it, yet they will always look for ways to cut expenses. Consolidation by any practical means is the obvious response and will be evaluated repeatedly. Technology is another way; the use of cheap RFID tags is an example of an efficient method for raising LTL terminal throughput and reducing delivered cost.

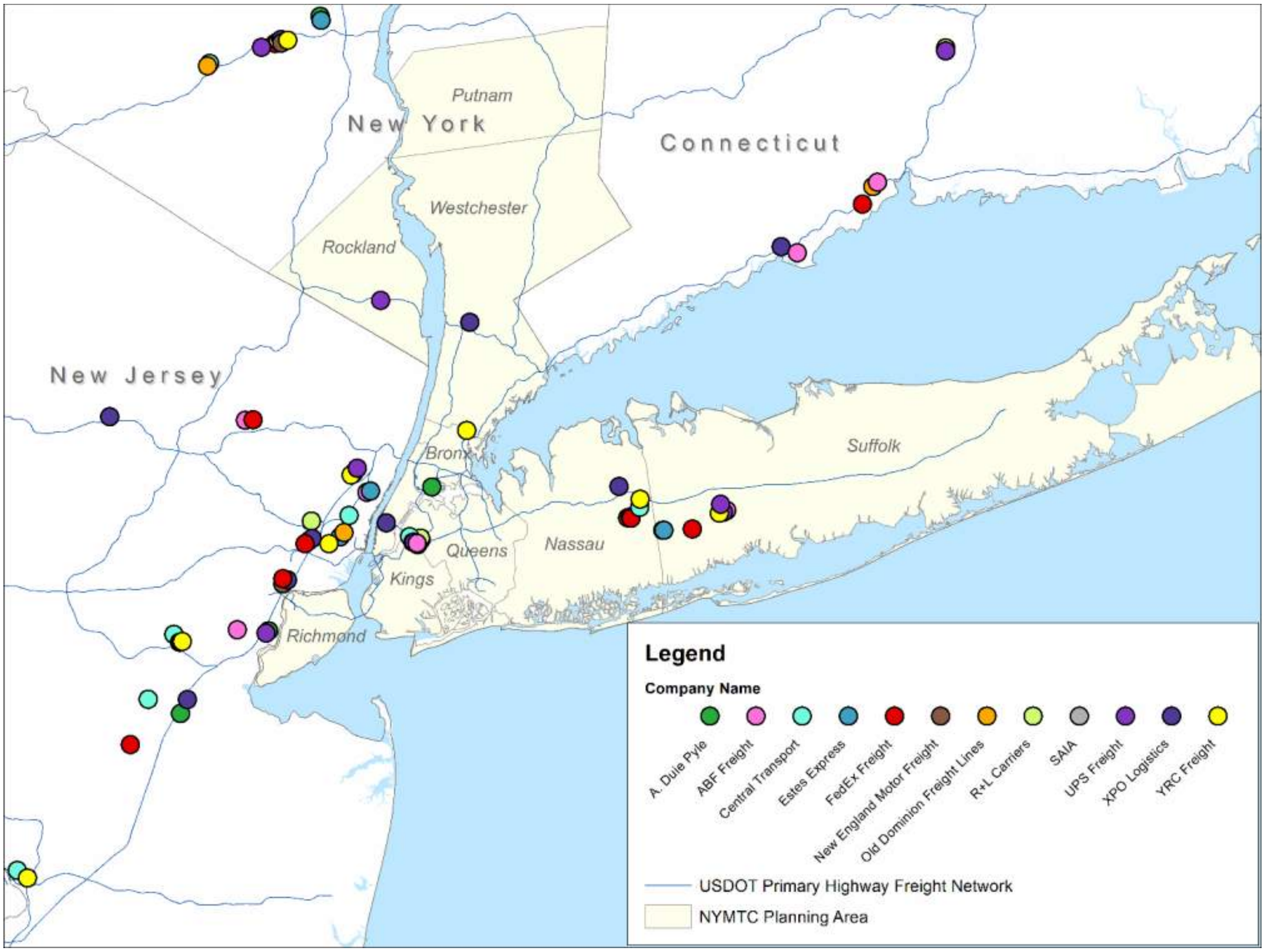
3.2.2 Terminal operations

LTL operates through networks of city terminals and hub terminals. The hubs are major intercity sorting locations but have local pick-up and delivery (P&D) functions as well. The terminals are cross-docks and do not store goods. City terminals must be situated so as to support morning delivery and afternoon pickup, allowing delivery as early as possible and pick-up as late as possible as a competitive requirement. There are 27 terminals[10] operated by major LTL carriers within the NYMTC region, and

[10] New England Motor Freight (NEMF) announced it was going out of business in February 2019. This was a surprise to the industry, which typically anticipates financial distress, and a short-term capacity shortage is apt to follow as shippers seek alternatives to this $400 million northeastern regional carrier. However, the history of motor carrier bankruptcies suggests the industry will absorb the traffic in time, perhaps with higher rates for some shippers. NEMF terminals may transfer to other carries, be taken over as cross-docks by shippers, or be sold for other uses.

another 49 terminals in surrounding areas within reach of the region, notably in northern New Jersey and Orange County, NY.

Figure 3.4 LTL Terminals In and Surrounding the NYMTC Planning Area



Source: Carrier web sites

Intercity linehaul schedules are a major constraint: off-peak P&D is not much of an option because delivery does not begin until the overnight linehaul arrives and has been broken down into city trucks, and pick-ups do not extend late into the evening so the linehaul departs on time. Linehaul runs on a fixed schedule and cannot be compromised. With little time flexibility remaining, the city operation faces a persistent challenge from congestion. LTL carriers contend with this by a) using more trucks and making fewer stops with each, which raises costs and harms productivity; and b) adding city terminals closer to more distant customers, which creates greater fixed expense. An important impact of larger LTL volumes in the NYMTC region therefore is more trucks running at peak hours, due both to the linehaul constraint and the productivity effects of congestion.

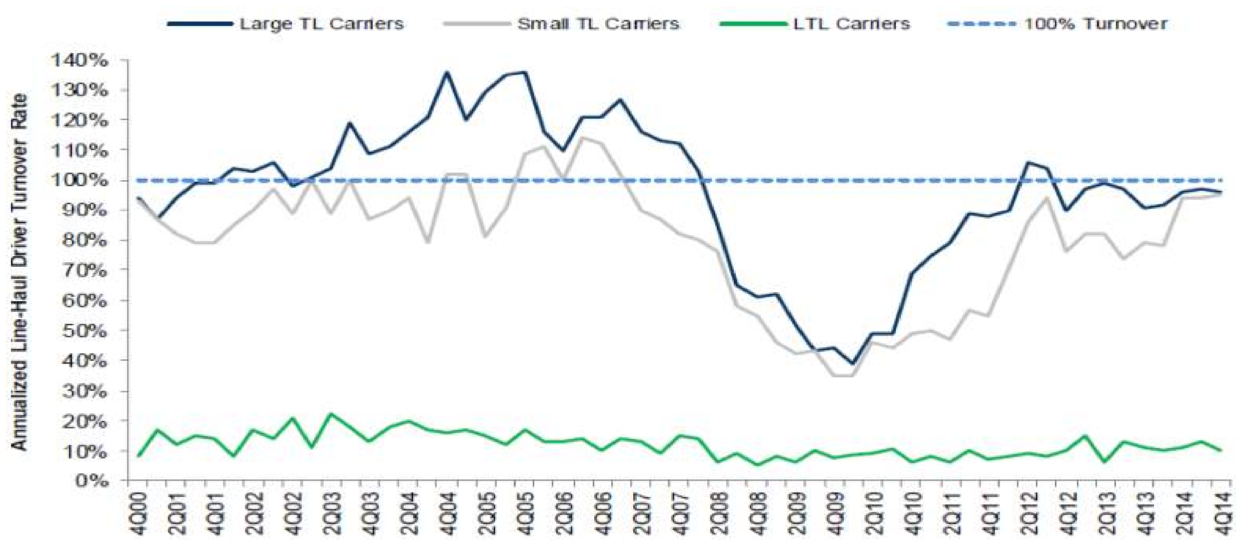
Terminals are concentrations of truck activity, and thus of emissions and perceived safety issues. Although higher LTL volumes will elevate both, mitigations are available. The technology associated with automated vehicles increasingly is being adopted and making trucks safer. FedEx Freight has an

LTL hub in Oklahoma City that runs 100 percent on natural gas, and while this fuel is an abundant local product in Oklahoma, there are substantial sources in western Pennsylvania as well.

3.2.3 Superior driver supply

LTL is an attractive driving job because city work is local with the driver retuning home nightly, and linehaul runs on regular schedules with frequent time at home. LTL driver turnover is around 10 percent, and compares very favorably to the turnover in truckload that approaches 100 percent. These are long-standing trends as Figure 3.5 from a few years ago illustrates, and have not changed in the time since. Its superior ability to seat trucks and deploy capacity has contributed to LTL traffic growth, an advantage that was heightened by the federal mandate for electronic driver logs that took effect at the beginning of 2018. Because of its fixed schedules, LTL operations were not greatly affected by the mandate, whereas truckload operations faced straitened work hours and lost effective capacity. One large shipper reported a 5-7 percent reduction in truckload availability in the first half of 2018, which is the kind of market opportunity that the LTL sector can and does exploit.

Figure 3.5 Driver Retention in LTL Far Exceeds TL



Source: American Trucking Association and Stifel Transportation Research, 7/15

3.3 Approximate Timing of the Effects

Because so much of the growth in LTL has been attributable to the rapid growth in E-commerce and associated warehousing/fulfillment trends, it is reasonable to expect that the anticipated timeline for E-commerce growth described in Section 2.3 would indicate a correlated growth in shipments moving by LTL.

4.0 Vehicle Automation

4.1 Trends

4.1.1 Automated and autonomous vehicle technologies

The use of automated vehicle technologies in trucking is evolving quickly. While passenger cars garner much of the media attention, an increasing number of trucks are utilizing sensor, communications, and/or processing software technologies for both steering and braking assistance. The benefits of greater vehicle automation are substantial. As outlined by the National Highway Traffic Safety Administration, they include improved safety and efficiency, lower economic and societal costs, and greater convenience and mobility.[11] The Society of Automation Engineers' automation levels classification scheme is the industry standard in terms of measuring the degree of automation in a vehicle (see Figure 4.1). Currently the highest level of truck automation commercially available is "driver assistance" (Level 1). Partial and conditional automation are in the pre-commercial stage, and high and full automation are in research and development.[12]

Figure 4.1 Levels of Automation

Society of Engineers (SAE) Automation Levels		
0	No Automation	Zero autonomy; the driver performs all driving tasks.
1	Driver Assistance	Vehicle is controlled by the driver, but some driving assist features may be included in the vehicle design.
2	Partial Automation	Vehicle has combined automated functions, like acceleration and steering, but the driver must remain engaged with the driving task and monitor the environment at all times.
3	Conditional Automation	Driver is a necessity, but is not required to monitor the environment. The driver must be ready to take control of the vehicle at all times with notice.
4	High Automation	The vehicle is capable of performing all driving functions under certain conditions. The driver may have the option to control the vehicle.
5	Full Automation	The vehicle is capable of performing all driving functions under all conditions. The driver may have the option to control the vehicle.

Source: National Highway Traffic Safety Administration

Multiple vehicle manufacturers are actively engaged in the development of autonomous trucks, which given the relative economic incentives, are expected to outpace autonomous passenger vehicles in terms of widespread commercial adoption. One notable example is Embark. This company is testing a system that automates the freeway portion of a truck's journey, and allows the driver to take over to navigate the more complex local roads. The approach is designed to enable truck drivers to complete more journeys per day, while spending less time actually driving. Other companies with promising pilot programs include Waymo (a subsidiary of Google's parent Alphabet), Telsa, semiconductor company Nvidia in partnership with Paccar, maker of Kenworth, Peterbilt and DAF truck brands, and commercial

[11] https://www.nhtsa.gov/technology-innovation/automated-vehicles-safety

[12] Source: "Automation in the long haul: Challenges and opportunities of autonomous heavy- duty trucking in the United States"

supplier Wabco. These are just some of the more high-profile examples in a list that includes nearly 50 different manufacturers. Moreover, research and development is not confined to the private sector. The U.S. Army plans to deploy dozens of autonomous trucks in 2019.

A related approach to autonomous vehicle operation drawing significant interest is platooning. Truck platoons use vehicle-to-vehicle communications and autonomous vehicle control technology to electronically “tether” tractor-trailers together in a convoy formation. One of the primary benefits of platooning is greater fuel efficiency, which stems from reduced aerodynamic drag on the following vehicle(s). According to the North American Council for Freight Efficiency, the average fuel savings of two-truck platooning is approximately four percent, after accounting for real world conditions.[13] Other potential benefits include reduced driver stress, fewer accidents, less congestion, and lower carbon emissions. Several private sector companies are in the advanced testing stage for truck platooning, including Peloton, Daimler and Volvo, as well as the US Army.

The federal government has been actively engaged in the development of autonomous vehicles in recent years. In 2016, the US Transportation Secretary announced a 10-year, $4 billion plan aimed at accelerating the development, adoption and integration of safe autonomous vehicles. Under the plan, the government will fund large-scale pilot programs, and work with both public and private-sector participants to ensure a shared framework for connected and autonomous vehicles.[14] For example, the DOT-funded Ann Arbor Connected Vehicle Environment, Connected Vehicle Pilots Program and the Advanced Transportation and Congestion Management Technologies Deployment Program have combined over $150 million in Federal and State funding for vehicle communications technologies such as vehicle-to-vehicle (V2V).[15] In an effort to provide a flexible regulatory environment that encourages its core mission of promoting safety without sacrificing innovative, the US Department of Transportation released its Federal Automated Vehicle Policy in 2016, followed by Automated Driving Systems 2.0: Vision for Safety in 2017, and Preparing for the Future of Transportation: Automated Vehicle 3.0 in 2018, which provides more detailed guidance and best practices in terms of testing and deployment of automated technologies. It also focuses on greater transparency and public engagement in the process in order to improve public support and confidence, which is viewed as critical to the adoption of such technologies

4.1.2 Autonomous delivery technologies

Congested areas represent a significant challenge for both autonomous and connected vehicles. The interaction of trucks, cars, cyclists, and pedestrians – all moving in different directions at different times for different purposes – presents automated vehicles with a huge amount of variability and unpredictability. In fact, the vehicle platooning automation currently in development generally functions with at least some degree of human control once the platoon exits the freeway. Similarly, while driver assistance technologies greatly enhance truck efficiency and safety on local roadways, development of higher levels of automation often focus on long-haul, over-the-road operation.

The relatively slower speeds at which vehicles operate in local areas may assist automated vehicles in safely identifying, monitoring, and navigating those areas, assuming the development of the appropriate

[13] http://nacfe.org/technology/two-truck-platooning/

[14] https://www.transportation.gov/sites/dot.gov/files/docs/DOT-fy-17factsheet.pdf

[15] https://www.transportation.gov/sites/dot.gov/files/docs/policy-initiatives/automated-vehicles/320711/preparing-future-transportation-automated-vehicle-30.pdf

(Footnote continued on next page...)

technology.[16] This, combined with the costly nature of local deliveries, has inspired numerous potential innovations, including fully autonomous delivery vehicles being developed by both Udelv and Nuro. For the New York area specifically, one could envision a scenario in which a driverless vehicle operating in conjunction with a delivery employee, or a delivery "robot," such as the food delivery bots operating in Washington, DC and shown in Figure 4.2, and parcel delivery bots being tested elsewhere, could circumvent some of the delays caused by the perennial lack of suitable street parking in front of many residences. The vehicle could stop to allow the employee to disembark with the package(s), drive around the area while the employee delivers the packages, and return to pick up the employee once the transaction had been completed – subsequently moving on to the next location.

Figure 4.2 Delivery Robot in Washington, DC

Source: Washington Post

4.1.3 Positive Train Control and Other Rail Technologies

Several types of advanced vehicle automations are being implemented by freight railroads in the US and globally. These include:

- Autonomous freight trains, with and without drivers on board
- Positive Train Control (PTC)
- Other safety applications

Autonomous Trains

Internationally, the only known fully autonomous freight railroad system is in Australia. The system is part of the Australia Rio Tinto mining company, and began fully autonomous train operations on an approximately 62-mile stretch of track in Western Australia. This Rio Tinto train is equipped with a variety of sensors (e.g., radar, cameras, [animal] collision sensors) and with a switch to toggle between autonomous operation or operation with an operator on board. In 2017, Rio Tinto's "AutoHaul" project began with information technology enhancements, progressed to autonomous trains with drivers on board, and finally to a demonstration trip featuring autonomous service with no engineer on board for backup. This is believed to be the first-ever linehaul trip without an engineer on board.

[16] "Self-Driving Vehicles in Logistics"

Figure 4.3 Rio Tinto "AutoHaul" Autonomous Locomotive

Source: https://www.railwayage.com/regulatory/fra-rfi-automation-railroad-industry/

In the US, remote controlled locomotives (RCLs) are commonly used within switching/classification yards, but not outside of yard boundaries. US Class I railroads began implementing RCL operations starting in January 2002. Operating environments have included yards, industrial spurs and sidings, and some main tracks and sidings/spurs. Remote control operators (RCOs) must adhere to relevant operating rules in effect during RCL operations and may have additional responsibilities depending on the operating environment. Some of these responsibilities may include communication with a yardmaster or dispatcher, minor train handling on ascending and descending grades, car handling, and communication with other crews operating in the vicinity of the RCL. RCOs on Class I railroads are generally switchmen who receive special training to become Federal Railroad Administration-certified RCOs, although a small minority of RCOs are also FRA-certified locomotive engineers who have experience operating a locomotive. Switchmen were never traditionally trained to operate a locomotive.[17]

Rio Tinto Automated Freight Train Experience

2 October 2017. Rio Tinto has successfully completed the first fully autonomous rail journey at its iron ore operations in the Pilbara region of Western Australia as the company progresses toward full commissioning of the AutoHaul® project in late 2018.

The nearly 100 kilometre pilot run was completed without a driver on board, making it the first fully autonomous heavy haul train journey ever completed in Australia. The journey was completed safely, being closely monitored in real-time by Rio Tinto teams and representatives of the Office of the National Rail Safety Regulator, both on the ground and at the Operations Centre in Perth. The successful pilot run from Wombat Junction to Paraburdoo is a significant step toward full commissioning of AutoHaul® in 2018 once all relevant safety and acceptance criteria have been met and regulatory approvals obtained.

Rio Tinto Iron Ore chief executive Chris Salisbury said "This successful pilot run puts us firmly on track to meet our goal of operating the world's first fully-autonomous heavy haul, long distance rail network, which will unlock significant safety and productivity benefits for the business. "Gains from AutoHaul® are already being realised including reduced variability and increased speed across the network, helping to reduce average cycle times. "Rio Tinto is proud to be a leader in innovation and autonomous technology in the global mining industry which is delivering long-term competitive advantages as we build the mines of the future. New roles are being created to manage our future operations and we are preparing our current workforce for new ways of working to ensure they remain part of our industry."

Rio Tinto's focus on automation technology and innovation is improving safety, is better for the environment and boosting productivity. The AutoHaul® project is focused on automating the trains that are essential to transporting the iron ore to our port facilities. Trains started running in autonomous mode in the first quarter of 2017. Currently about 50 per cent of pooled fleet rail kilometres are completed in autonomous mode (with drivers on-board) and 90 percent of pooled fleet production tonnes are AutoHaul® enhanced. Rio Tinto operates about 200 locomotives on more than 1,700 kilometres of track in the Pilbara, transporting ore from 16 mines to four port terminals.

Source: http://www.riotinto.com/media/media-releases-237_23264.aspx

[17] Federal Railroad Administration, A Comparative Risk Assessment of Remote Control Locomotive Operations versus Conventional Yard Switching Operations May 2006

Figure 4.4 Remote Control Locomotive Operations are Common in US Railyards

Source: Federal Railroad Administration

Currently, US passenger and freight railroads do not have a fully autonomous rail operation in revenue service. However, railroads commonly use automated systems for dispatching, meet and pass trip planning, locomotive fuel trip time optimization, and signaling and train control, in addition to remote controlled yard operations. Modern locomotive cabs are equipped with intelligent information systems designed to provide operating crews with up-to-date situational awareness as train sensor data, and alarms are continuously updated and displayed in operator consoles within the cab. Railroads often now utilize energy management technology (the equivalent of automobile cruise-control) to optimize fuel consumption based on specific operational and equipment factors, as well as movement planner systems designed to optimize, in real time, train movements on the rail network.

The US railroad industry has been engaged by the US Department of Transportation in discussions regarding connected and autonomous vehicle policy, and the Association of American Railroads (AAR) has argued for a 'level playing field' with respect to other modes, allowing it to benefit from increased automation opportunities including development and deployment of autonomous trains. US freight railroads typically run trains with a crew of one or two. Anecdotally, we have heard from one Class I railroad that one benefit of increased automation technology would be the ability to maintain minimum crew sizes – not eliminating crews through fully driverless operations, but maintaining or in some cases reducing crew sizes.

We are not aware of any immediate plans for full automation of train operations outside of yards, and believe the earliest US implementation of highly automated or fully automated freight rail service is likeliest in situations comparable to Rio Tinto in Australia – with consistent unit train loads of heavy non-hazardous materials, moving relatively short distances through relatively unpopulated areas, in relatively protected corridors. Applications of highly or fully automated trains in more complex network operations over longer distances, in densely developed areas with large populations and high risks from at-grade crossings, with high value and/or hazardous cargo, and in situations where multiple freight railroads and multiple passenger railroads share infrastructure, seem far less likely in the foreseeable future for practical and regulatory reasons. It's not impossible they could be introduced into the NYMTC planning area at some point in the future – particularly if appropriately controlled and protected corridors are identified -- but it would only be after the technologies and operations are proven in less-sensitive regions, and supportive regulations are in place. As a result, fully automated trains in the NYMTC are considered unlikely in the near term.

Positive Train Control

Railroads are implementing statutorily mandated positive train control (PCT) technology. PTC is a processor-based/communications-based train control system PTC helps to prevent train accidents by automatically controlling train speeds and movements if a train operator fails to take appropriate action in certain operational scenarios.

By federal law, PTC must be installed on all mainlines carrying passengers or toxic-by-inhalation materials. AAR reports that as of July 2018, Class I freight railroads have: equipped 98% of required locomotives with PTC; installed 99% of required wayside units; installed 100% of required radio towers; trained 99% of required employees; and implemented PTC on 70% of required route miles. The deadline for full installation is December 2018, and the deadline for full operation – including interoperability across different passenger and freight systems – is December 2020.

Specifically, PTC is designed to prevent: train-to-train collisions; derailments caused by excessive train speed; train movements through misaligned track switches; and unauthorized train entry into work zones. For freight railroads, these types of accidents occur far less frequently than accidents due to track or equipment failure, vehicles improperly crossing tracks at grade, and trespassing on tracks. PTC is not designed to prevent those types of accidents. Efforts by USDOT and others to quantify the value of accidents prevented by PTC have found that benefit does exist, although the benefit-cost ratio is low due to high costs.

Overall, PTC will provide some safety benefit in the NYMTC planning area by eliminating risk from certain kinds of train accidents on certain rail lines, although other risks will remain to be addressed through other means.

Other Safety Benefits

PTC is designed to allow trains to 'talk to each other' – not to motor vehicles, so there is no opportunity to link PTC with other autonomous/semi-autonomous vehicle operations. However, there are important opportunities for other technologies that would allow rubber-tired vehicles to be aware of – and automatically respond to – the proximity of trains at grade crossings, reducing the risk of highway-rail crashes. This would require the installation of signal-sensing equipment in rubber tire vehicles, signaling systems at grade crossings, and mechanisms to trigger the signals on train approach. This might be similar to adaptive cruise control, which slows a car when it approaches a leading vehicle too closely;

potentially, a car could be prevented from driving forward during a period when the crossing is "closed" by the signal system. We believe this concept has the potential to dramatically reduce the single largest safety risk from freight rail operations in the US, and the region. While the responsibility for regulation is largely at the Federal level, the responsibility for implementation is shared among multiple stakeholders – federal and state governments, the railroad industry, and the auto industry. NYMTC and its state and regional partners could and should play a meaningful role in the discussion

Another application of automated technology is the use of remote sensing equipment, including drones, to perform safety and condition inspections of rail tracks and rights-of-way. These technologies are already coming into use, and allow railroads to inspect more track more frequently at lower cost.

Both of these applications are, we believe, very strong candidates for near-term implementation, and they could each provide very significant benefits in the NYMTC region.

4.1.4 Marine Terminal Automation Technologies[18]

Most container terminals in the United States and globally have implemented "data automation", i.e., the entry or tracking of terminal information without human oversight or engagement. Data automation involves instrument-based data acquisition, database updates, and transmission or dissemination of data. Data automation includes Optical Character Recognition, Radio-Frequency Identification, Differential Global Positioning Systems, Radio Positioning Systems, Inertial Navigation Systems, Automatic Machine Telemetry, Automatic Inventory Management, Wi-Fi, Wi-Fi Local Area Networks, and related systems. Data automation is now ubiquitous in the maritime environment, with much greater deployment than automated equipment. Optical Character Recognition for reading container numbers and truck license plates is widespread. Radio Frequency Identification for identifying trucks, chassis and container handling equipment is also widespread; RFID for identifying containers was tested and found to be practicable in small, controlled fleets, but is not widespread. Bar Code Scanning is not widely used in the maritime environment because of the difficulty of maintaining bar code readability in rough environments.

Additionally, some terminals in the United States and globally have implemented varying degrees of "machine automation" or "robotization", the operation of equipment with minimal human oversight or engagement. The extent of "automation" varies considerably from terminal to terminal, and the definition and fundamental nature of "automation" has become less homogeneous as more and varied technologies become available and are applied. Generally speaking, automation is the replacement of human direction of the work with programmatic direction, and semi-automation implies alternation between human and programmatic direction. In marine terminals, full automation involves machine automation of yard cranes for storage and retrieval, as well as the transport units used to move cargo across the terminal; semi-automation involves automation of only the cranes, leaving transport under manual control. Through 2020, about 90% of existing marine container terminals worldwide are expected to remain Fully Manual, with all equipment driven by human operators; around 7% are expected to be Semi-Automated; and around 3% are expected to be Fully Automated.

Automated cranes include Automated Stacking Cranes, Cantilever Rail-Mounted Gantry Cranes, Overhead Bridge Cranes, and Automated Rubber-Tired Gantry Cranes. Some level of automation has

[18] Source: WSP, TBA, and RVE Management. *Marine Terminal Automation, State of the Craft, November 2017*. Information abstracted from confidential report.

been applied to Ship-to-Shore Cranes. Automated Straddle Carriers act as cranes for storage and retrieval. Automated transports include Automated Guided Vehicles, Automated Straddle Carriers, and Automated Shuttles. Where automated cranes and automated transports interact with no humans present, the interface is generally fully automated. Where automated cranes and manual transport interact, or where the interaction is highly variable, the crane comes under human control and the interface is semi-automated.

At least a dozen different combinations of manual and automated crane and transport machine classes have been deployed successfully into sustained commercial service. Most of the working systems rely on Automated Stacking Cranes for storage and retrieval. A few use Automated Straddle Carriers, Automated Overhead Bridge Cranes, Rail-Mounted Gantry Cranes, or Rubber-Tired Gantry Cranes. Except for Automated Straddle Carriers, the cranes in these other systems are semi-automated for storage and retrieval. Most of the current working systems have street trucks served directly by Automated Stacking Cranes at semi-automated Storage/Truck Interfaces. In full automation, where transport is also automated, the dominant machine is the Automated Guided Vehicle, with some use of Automated Straddle Carriers or Automated Shuttles. In semi-automation, where transport is manual, Automated Stacking Cranes are typically served by Manual Straddle Carriers or Manual Shuttles, while the other crane types are typically served by Manned Utility Tractors.

Figure 4.5 First Automated Terminal at Delta SeaLand, Rotterdam

Figure 4.6 Automated Stacking Crane at Burchardkai, Hamburg

Source: WSP

Figure 4.7 Automated Guided Vehicle, Altenverder

Source: WSP

Figure 4.8 Automated Straddle Carrier

Source: MNE B.V.

Challenges experienced to date with Fully Automated and Semi-Automated terminal systems include:

- Maintenance. Workers must still visit the automated portions of terminals for maintenance and repair activities, requiring special security, safety interlocks, and physical protections that are integrated through the Equipment Control System.

- Interoperability. Inter-Box Connector handling has proven difficult to automate because of the wide variability in types, even within one vessel. Automated Lashing Platforms are seeing their first production use, but most automated terminals still rely on manual "coning", either on the ground or on a crane-mounted platform.

- Truck exchanges. Exchanges between trucks and container storage are difficult to fully automate because of the possibility of trucker unpredictability and positional variation. However, much progress has been made and, although human input has not been eliminated, it may well be reduced.

- Flexibility. Variability in cargo handling types, including out-of-gauge and non-container cargo, typically requires human control to resolve.

- Data controls. Imperfect data is a persistent problem that reduces automation performance. Data security is a problem for automation, as it is for any other system that relies on networked data handling. Unauthorized access may lead to data corruption that can, if severe enough, halt automated operations. The control of automated systems by humans proves to be cumbersome, as the complexity of the automated operation is not balanced by clarity and accessibility of system data provided by the automated system. Integration between management and automation control software systems continues to be challenging.

- Standardization. Technology continues to advance rapidly on multiple fronts and, lacking established performance standards, each implementation of automation technology is customized, making standardization nearly impossible.

Overall, while marine terminal automation can offer significant benefits, experience and analysis suggest that the extent and nature of these benefits depends on specific conditions at individual ports.

- Vessel turnaround. Vessel service performance with fully-automated systems is about equal to that of their equivalent manual systems measured on an hourly basis. Semi-automated systems that use Manual Straddle Carriers or Manual Shuttles for transport provide faster vessel service because they are more flexible in responding to the complexities of export container stowage. However, these systems retain more restrictive work hours than fully-automated systems, so total daily production may not be very different. Gate Service is generally faster with both full- and semi-automated systems.

- Land utilization. Land utilization efficiency is about the same with automated systems as with the densest manual system; while the density in the core area of an Automated Stacking Crane yard is quite high, that core is surrounded by substantial open circulating area, whether transport is automated or manual.

- Environmental effects. Automated and semi-automated terminals have smaller environmental footprints than manual terminals because they use more electric equipment, they have less lighting, and they are quieter. The drive to electrification in support of emissions reduction is giving automated systems, which are largely electric, a regulatory advantage in some places.

- Safety. Automated and semi-automated terminals are safer than manual terminals. Worker loss-time Incident rates are lower in automated terminals, and, to date, there have been zero serious casualties in any of the world's automated terminals. Automated and semi-automated terminals incur far less damage to containers, cargo, and equipment because of more precise motion control.

- Cost. Operating labor usage and unit operating costs tend to be significantly lower in automated terminals compared to Fully Manual terminals, but automated terminals incur significantly higher costs for capital equipment and information system maintenance. Automated terminals offer their clearest cost advantage for new ("greenfield") port development, where development can start without loss of revenue or customer base, and high labor-cost operating environments. The advantages are less clear for terminals that require extensive retrofitting, or benefit from low labor costs or high extant labor efficiency.

4.2 Impacts on the Supply Chain

4.2.1 Driver hours-of-service and driver shortages

The development of vehicle automation could significantly address some of the biggest challenges facing the trucking industry today. One prime example is hours-of-service for drivers. Regulations stipulate that a driver can be on-duty for up to 14 consecutive hours, drive up to 11 of those hours, and must rest at least 10 hours before starting a new shift. The goal is to promote safe driving and minimize driver fatigue. However, the American Transportation Research Institute's annual survey of motor carrier executives and commercial drivers consistently ranks hours-of-service as a top issue, primarily due to the rigidity it imposes. Automation technologies could offer a partial solution. With high or full vehicle automation, a driver could potentially sleep in the sleeper berth during long stretches of interstate highway while the vehicle remains under autonomous control. Thus drivers would be able to rest and 'drive' simultaneously, allowing for greater flexibility as well as productivity.[19]

Autonomous trucking could also address the issues of driver shortage and driver retention. According to American Trucking Association figures, the trucking industry was short an estimated 36,500 drivers in 2016. That number is projected to climb to 174,000 by 2026, if current trends continue.[20] Higher automation could relieve some of the stress and monotony of driving long hours, thereby making truck driving more attractive as a career. At the same time, high and full automation could allow drivers to work on other tasks such as logistics while the vehicle is moving, increasing productivity and thereby reducing the number of trucks and drivers needed to move the nation's freight.[21]

4.2.2 Cost of trucking relative to other modes

Vehicle automation can impact trucking costs in a variety of ways. For example, predictive cruise control, which combines cruise control with GPS and topographical data to optimize performance varying terrains, reducing fuel consumption by an estimated one or two percent.[22] Platooning can produce another four percentage point reduction in fuel costs, on average.[23] While more difficult to quantify at this stage, there are clearly cost savings associated with greater labor productivity and increased safety as well. Meanwhile estimates of the per vehicle cost of implementing such technologies range from a few thousand dollars for individual items such as lane assist, to twenty to thirty thousand dollars for full automation. Nonetheless the return on investment could be substantial for a $150,000 truck that drives hundreds of miles daily.[24]

The aforementioned fuel savings generally apply to long-haul trucking, which is a direct competitor to rail freight, as opposed to short-haul trucking, which is considered a complement to rail. The Center for Transportation Studies' "Emerging Freight Truck Technologies: Effects on Relative Freight Costs"

[19] "Identifying Autonomous Vehicle Technology Impacts on the Trucking Industry"

[20] https://www.trucking.org/article/NewReportSays-National-Shortage-of-Truck-Drivers-to-Reach-50,000-This-Year

[21] "Identifying Autonomous Vehicle Technology Impacts on the Trucking Industry"

[22] "Automation in the long haul: Challenges and opportunities of autonomous heavy- duty trucking in the United States"

[23] https://nacfe.org/technology/two-truck-platooning/

[24] "Automated Trucks The next big disruptor in the automotive industry?"

attempts to measure the fuel costs savings of autonomous and/or connected vehicle technologies and the subsequent impact on rail demand. The authors assumed a gradual implementation of these technologies over three phases. In first phase, the fuel cost savings for trucking and the successive reduction in demand for rail was relatively small. However, by the final phase, the study showed roughly a 40 percent decline in per mile fuel costs for trucks and about a 45 percent decline in rail demand as a result.

4.2.3 Safety

Improved road safety is widely quoted to as a potential benefit of automated truck technologies. An often-cited statistic to back up this statement is the fact that approximately 90 percent of commercial truck accidents are caused or worsened by human error, either by a truck driver, other drivers, other vehicle passengers, cyclists or pedestrians. Currently there is some evidence that recently implemented technologies such as forward collision warnings and automatic emergency braking systems do enhance safety. However, there is no real-world data available on the safety impacts of vehicles with higher levels of automation. In fact, some experts argue that Level 3 automation, which requires human intervention, could even increase traffic collision.[25] Others argue that during the assumed transition period in which conventional and self-driving vehicles are sharing the road, the number of accidents might actually increase, at least for the conventional vehicles.[26] One fact that experts do agree on is the need for additional testing to fully understand the safety potential of autonomous technologies and their impact on the overall transportation system.

4.2.4 Production/Distribution Networks

Autonomous vehicles are already being utilized inside domestic warehouses to load and unload goods and to move products around. Overseas, ports are using driverless vehicles to quickly and efficiently transport containers between docks and storage areas. Going forward, there are ample opportunities for greater use of automated technologies throughout distribution networks. Whether this could have long-term repercussions on the location of facilities along the supply chain remains unclear. For now, the impact is likely to be limited, particularly as the push toward autonomous trucking will probably focus on long-haul freight in the near term.

4.2.5 Influence of PTC and Other Rail Technologies

From the discussion in Section 4.1.3, the anticipated influence of PTC and other rail technologies can be summarized as follows:

- Automated operations are unlikely to be a factor in the NYMTC planning area for the foreseeable future
- Positive Train Control, with full implementation by 2020, will avoid certain types of rail accidents on certain lines, but will not address the majority of risk factors.

[25] "Automation in the long haul: Challenges and opportunities of autonomous heavy-duty trucking in the United States"

[26] Road Safety with Self-Driving Vehicles: General Limitations and Road Sharing with Conventional Vehicles"

Other advanced technologies – particularly automated track/equipment inspection and at-grade crossing information/control systems for motor vehicles – offer significant near-term potential to improve rail operations and safety.

4.2.6 Influence of Marine Terminal Automation

As previously mentioned, the extent and nature of effects from marine terminal automation will depend on specific conditions at individual ports. Based on current information, we expect the following for the NYMTC planning area:

- Marine terminals will build on and advance their data automation efforts. Port and operators are continuing to invest in gate integration, appointment systems, and other systems that can improve truck movements.

- Given that the region's marine terminals are long-established, and no major new builds are anticipated, the region's ability to implement or benefit from semi automation or full automation will be limited. Retrofitting to automation is very expensive, and with PANYNJ and New York City emphasizing privatized capital development of marine facilities – as well as the retention and creation of jobs for skilled workers -- significant automation retrofits seem unlikely in the foreseeable future.

- Most other US east coast ports are in comparable positions, so the NYMTC planning area should not gain or lose significant market share based on automation. Virginia Port Authority is probably the leading US East Coast adapter for automated technologies, and is performing a staged conversion of the Norfolk International Terminal to automated stacking cranes, taking advantage of technologies and systems developed for APMT Portsmouth – but whether this leads to increased competitiveness is to be determined. We believe Savannah and Charleston, which have developed valid and productive manual-based systems, will remain committed to those models. Potential improvements at Canadian or Florida ports, if any, would be of little effect as these are not competing for markets served by NYMTC planning area ports.

Overall, automation of the marine terminals themselves is likely to have limited effects on freight volumes or logistics for the region. The more important consideration – and one that could have significant impacts – is automation of landside access to and from marine terminals via improvements to truck and/or rail. To the extent that ingress and egress to the ports can be improved – with respect to reliability, travel time, safety and security, and/or overall cost – the region's ports would become more attractive and competitive for marine business. This in turn could lead to attraction of freight from competing ports and higher than baseline growth.

4.3 Approximate Timing of the Effects

4.3.1 Trucking

There are significant barriers to the commercial integration of Level 3-5 automated trucks. In terms of technology, the hardware issues, such as sensors, vehicle-to-vehicle communication, and vehicle control, are relatively minor. However, the software issues, including spatial issues, human-machine-interface and mapping and path planning/control, need advanced development.[27] There are also significant infrastructure, legal and liability issues that must be resolved.

Another significant hurdle is societal acceptance of autonomous vehicles as trustworthy and safe. As previously mentioned, the federal government is actively seeking to overcome some of these obstacles through pilot program funding, a flexible regulatory environment, and greater transparency. Additionally, a recent report by the National League of Cities indicated that local government are also getting involved. As of 2018, more than half of America's large cities acknowledged efforts to get ready for autonomous vehicles, such as running pilots or passing new policy. This compares to less than 10 percent three years ago.[28]

There have been some notable forecasts with regard to vehicle automation. The National Highway Safety Traffic Administration (NHTSA) is projecting that the implementation of partially automated safety features such as lane keeping assist, adaptive cruise control, traffic jam assist and self-parking will occur by 2025. After 2025, NHSTA projects the availability of fully automated safety features, including highway autopilot. The International Transport Forum has forecast that high automation (level 4) could be available before 2030, with full automation (level 5) arriving around 2030.[29] IHS Automotive expects that annual sales of self-driving, heavy-duty trucks could reach 60,000 annually by 2035. That would amount to approximately 15 percent of trucks sales in the big, Class 8 weight segment.[30]

4.3.2 Rail

As noted above, full national PTC implementation is expected in December 2020. The timing for implementation of other safety systems addressing track/equipment inspections and at-grade crossings is to be determined, but these appear to be strong near-term opportunities.

4.3.3 Marine Terminals

As noted above, automation of the region's marine terminals seems unlikely in the foreseeable future. However, the implementation of truck and rail improvements serving the ports could be anticipated in the general timeframes described in Sections 4.3.2 and 4.3.3 above.

[27] "Automated Trucks The next big disruptor in the automotive industry?"

[28] https://www.smartcitiesdive.com/news/report-more-than-half-of-large-cities-are-preparing-for-avs/539971/

[29] Managing the Transition to Driverless Road Freight Transport

[30] https://www.trucks.com/2016/06/13/self-driving-truck-sales-forecast/

5.0 Warehouse Design and Automation

5.1 Trends

5.1.1 Greater throughput from one-story facilities

The number of DCs utilized in U.S supply chains has proliferated at an astounding pace. As Figure 5.1 depicts, the average tripled over the four years through 2017 and almost doubled over two years. This has been occurring among manufacturers as well as retailers, although the averages are larger among the latter. Consistent with this finding, overall deliveries of new warehouse and distribution space have more than tripled in the past five years.[31]

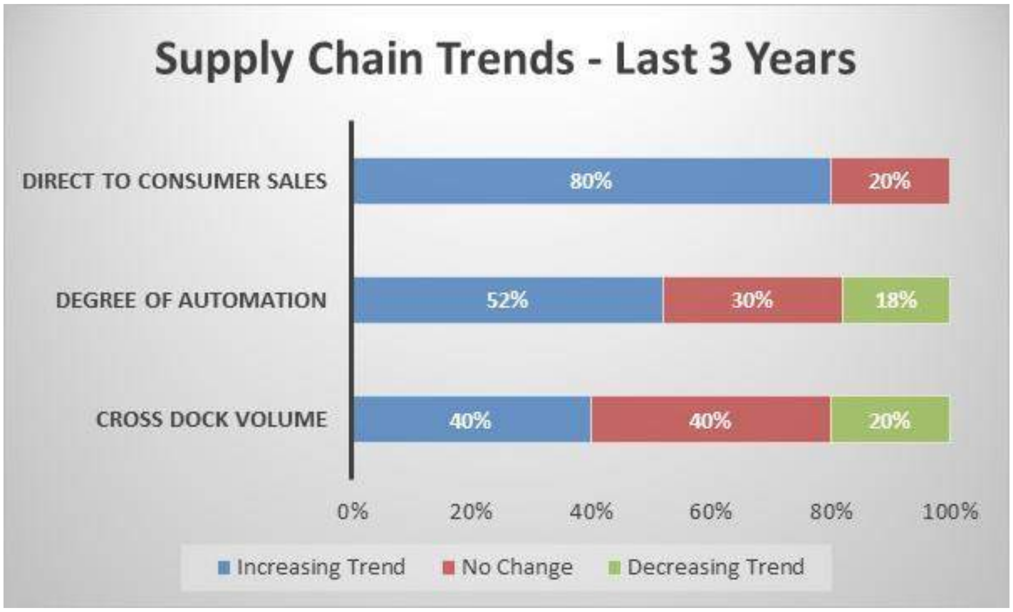
Figure 5.1 DC Proliferation in U.S. Supply Chains

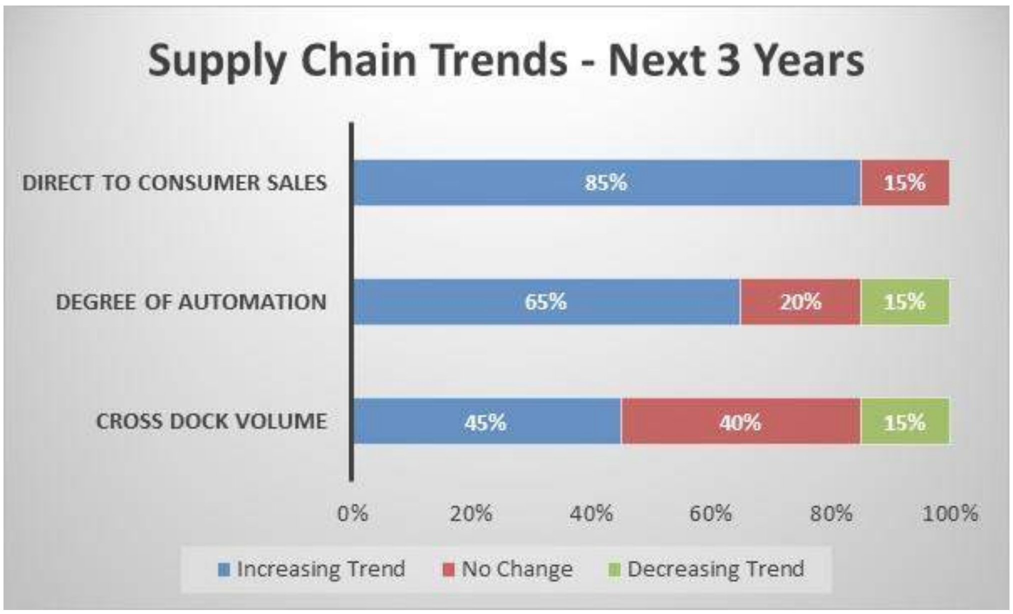
Source: Tompkins International, 2017

Meanwhile, the average size of DCs has dropped to 220,000 square feet (SF), a decline of 15 percent. In fact, the growth in DCs has occurred at the high (1 million+ SF) and low ends (under 250,000 SF), implying a multi-stage distribution strategy. The driver of this is continuing demand for faster time to market, of which a key component is e-commerce. Two trends have been moving together in this, as can be seen in Figure 5.2, growth in direct-to-consumer sales among manufacturers and retailers, and growth in their use of warehouse automation. The trends of course are related: use of more warehouse space increases costs; and automation reduces them. Automation also helps improve control of inventory, which is a crucial factor in a multi-stage system.

[31] "Urban infill: the route to industrial solutions", JLL Industrial Research, 2018

Figure 5.2 Supply Chain Trends, 2014-2016 (top), and 2018-2020 (bottom)





Source: Tompkins International, 2017

Automated warehouses can increase throughput per square foot (and thus per acre) by as much as three times. Aisles between storage racks can be narrower and the height of the racks taller, because robotics replace forklifts. This allows more product to be handled and stored horizontally and vertically, and it pushes warehouse ceiling heights well above 40 feet. Combinations of material handling and optical equipment enable greater precision in picking and packing of inventory, which enables management of larger volumes and greater varieties of products (called stock-keeping units, or SKUs). Companies interested in warehouse automation must weigh the high initial costs of acquiring the equipment and management systems, relative to the reductions in operating costs over time. As more companies have adopted automation, and the technology becomes ubiquitous, the barrier to entry into automation will likely continue to decline over time.

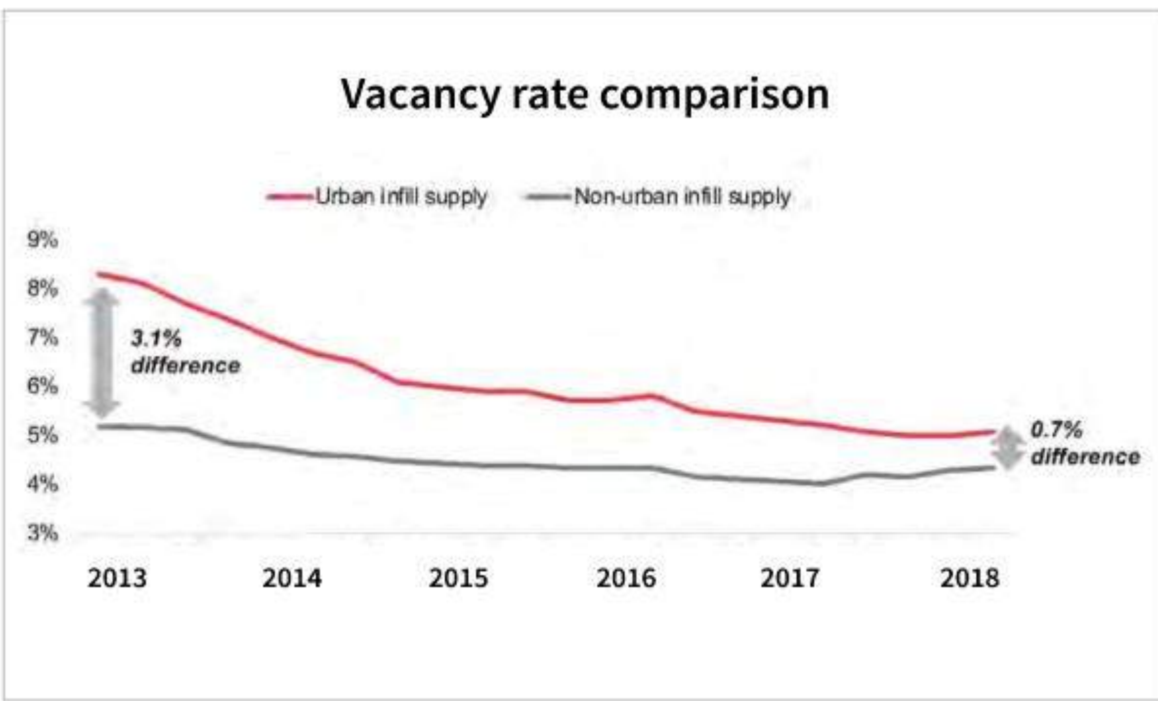
E-commerce fulfillment centers differ from traditional DCs in their requirement for greater labor input. This results from the small order sizes and varied SKU content typical of on-line consumer purchases. They are nevertheless significantly automated facilities. Equipment is used for material handling and to direct work flow, divert pass-through orders (where inbound product can be repackaged for outbound without further handling), and to limit labor involvement where possible.

5.1.2 New multi-story facilities ("urban infill")

Faster time to market is epitomized by the push in e-commerce toward same day and next day delivery. This requires more distribution staging closer to end-markets, with the emphasis on delivery more than storage. The demand for close-in facilities is met with urban infill - which simply means development or redevelopment in areas that are mainly built out - and it represents a major shift from practices of the past decades.

The supply of new urban infill properties has been flat at the same time that vacancy rates have rapidly declined, according to national research by the real estate firm JLL[32] and depicted in Figure 5.3. Rents are rising. This is leading to several responsive strategies, such as repurposing of existing facilities and companies leasing out portions of underutilized space. Redevelopment is possible for properties such as dying malls and big-box stores disrupted by e-commerce, as well as for obsolete warehouses and factories.

Figure 5.3 Comparative Vacancy Rate of Urban Infill



[32] JLL, ibid.

Source: JLL

Most dramatic is the arrival of multi-story, "vertical" warehousing in the U.S. Already in use overseas, the first multi-story facility opened in Seattle at the end of 2018. The Seattle property has 590,000 SF in under 14 acres in an urban setting just 5 miles from downtown. There are three stories, with an external ramp accommodating trucks with 53' trailers. Capacity per acre is tripled versus traditional one-story facilities, demonstrating how these designs are adapted to the smaller sites and costlier land characteristic of urban infill.

Figure 5.4 Prologis Seattle 3-Story Warehouse

Source: Prologis

Vertical designs are expensive. Construction of a new multi-story building can be at least twice the cost of renovating an existing facility, according to one estimate,[33] and the approach has its doubters. Vertical buildings work best in dense, high cost and high demand markets with large millennial populations (the key demographic for e-commerce) – all of which fits the metropolitan New York profile. At least three multi-story properties are planned for the New York region as of the start of 2019: in the Bronx, at Red Hook in Brooklyn, and a 4-story, 700,000 SF design at Maspeth in Queens (shown in Figure 5.5). A potential fourth is contemplated for air cargo handling near JFK International Airport, and Prologis has renovated a 2-story warehouse in the Bronx. Architects report the minimum lot size for these designs is three acres, although the sites planned in New York are larger.

[33] "Last Mile Delivery and the Rise of the Urban Warehouse", NAIOP, 3/17

Figure 5.5 4-Story Warehouse Planned in Maspeth, NY

Source: RXR Realty, LBA Logistics

5.1.3 Cross-docks vs. storage

Cross-docking refers to a simple re-sort system where shipments arriving in one trailer are moved into several other departing trailers bound to different destinations. LTL terminals are cross-docks, although our focus here is on applications for staging inventory in supply chains. The facility where transloading occurs typically is an oblong concrete dock with trailers arrayed on opposite sides: arrivals on one and departures on the other. In the re-sort, shipments are moved across the dock from trailer to trailer. The purpose of this is to maintain consolidation (i.e., full trailers, which cost less to transport per shipment), while allowing shipments to move to different destinations. They also enable goods in transit to *change* destination based on immediate demand for various products at the end-point (such as a store). This is a crucial advantage for supply chain management.

Warehouses store product inventory and send it on to end-points, also in response to demand. Compared to cross-docks, warehouses require more space and racks to hold goods, and more labor and material handling equipment to move them in and out of storage. They are therefore larger, more expensive buildings with higher operating costs. Cross-docks run 40,000-100,000 SF,[34] requiring less land (although they use more of it for truck parking) and are relatively cheap to own and operate. Since they serve similar functions for directing goods toward demand, one type of facility can substitute for the other to a degree. The limitation is that inventory acts as a buffer between the time when vendors can supply products and the time when the products are needed. Since they do not store goods, cross-docks cannot perform this function. When the time available to respond to demand is short – as happens in peak seasons, or for popular products, or when e-commerce merchants offer same day or next day delivery – then goods must be held close to the point of demand. This can be done through local inventory, or by directing goods in transit over local cross-docks. (A third alternative is to expedite goods by air, at a substantially higher cost).

The drive for faster time to market creates need for both types of facility. Cross-docks may seem better suited to metropolitan environments because of their more modest size. However, they depend upon

[34] "Driving Hard to Secure Last-Mile Logistics", Urban Land Institute, 2/18.

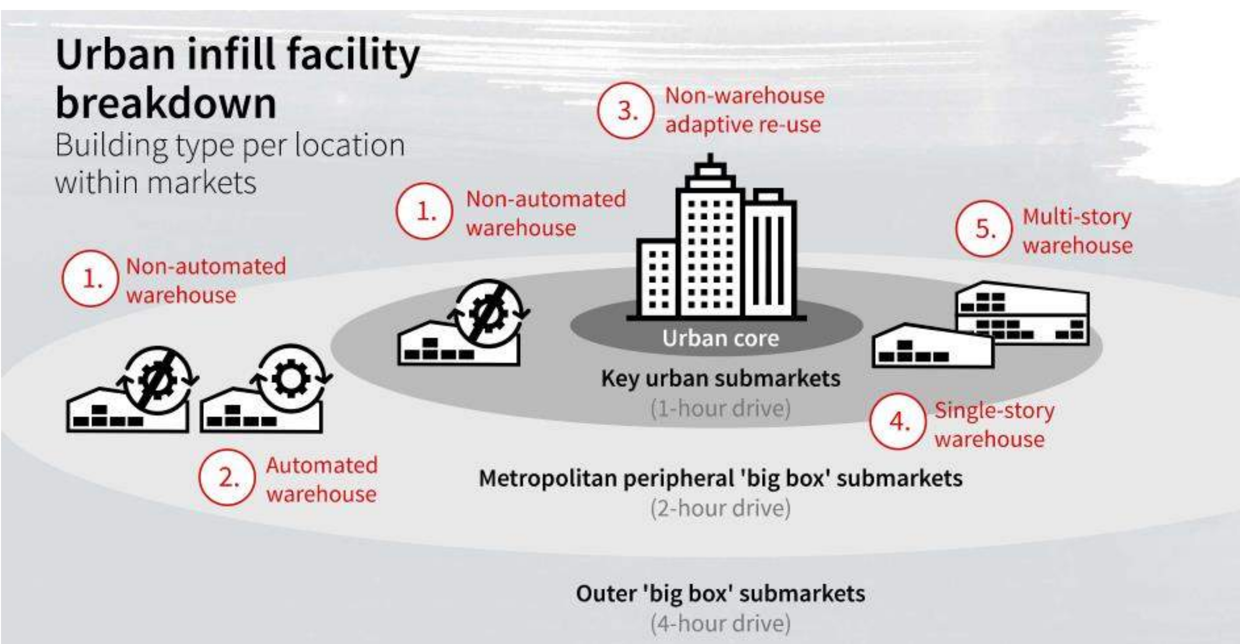
goods in motion (or goods stored in trailers, which are difficult to access). As response time shrinks - which same day and next day e-commerce service offerings are bringing about – portions of inventory must be held close by. Moreover, as the variety and volume of products moved in e-commerce channels expands, more of the nearby inventory is required. The net effect is that the use of cross-docks is expected to grow (as shown in Figure 5.2 above), yet not so dramatically as overall e-commerce trends.

5.1.4 Multi-stage networks

As the foregoing discussion implies, supply chains are moving toward multi-stage networks, with goods held at and directed from several points, and with facilities of different sizes and functions deployed along the chain. As noted above, the proliferation of warehouse and distribution centers among manufacturers and retailers is manifesting as greater numbers of facilities both at the high end and at the low end of the size spectrum. Large and increasingly automated DCs are situated at the outskirts of a region to serve multiple submarkets with big and diverse volumes of inventory held at the ready. The enormous growth of the Lehigh Valley as the main staging center for New York and the Northeast is a case in point. The regional DCs feed smaller DCs and cross-docks situated closer to and inside the submarkets.

The accompanying graphic (Figure 5.6) from JLL illustrates this emerging system. Large-scale automation resides at the regional rim with the big RDCs. This is a matter of degree, since smaller operations certainly have use for optical equipment and robotics – and will use more as costs decline. As the system moves in toward the urban core, the blend of facilities widens, with combinations of traditional warehouses, repurposing of established structures, and the introduction of the new, multi-story designs. This is a dynamic and evolving system, because the disruption of traditional retail patterns and the repercussions for manufacturers are still being played out and will be for a good many years. The players are experimenting and inventing, so that the shape of the ultimate system after the best approaches have been worked out has yet to be determined.

Figure 5.6 Urban Warehousing Submarkets



Source: JLL

One further point is important to note: supply chains will continue to seek to minimize inventory because it is expensive to own and hold. Inventory carrying costs typically total between 18 and 25 percent of the value of goods.[35] Thus, while the use of more distribution facilities inevitably brings more goods held in total, each staging point strives to remain lean. This implies that the connections between facilities – which is the transportation from one to the next – continue to have high service standards and low tolerance for delay because they enable minimal inventories. The entire system for accelerated time to market is a nested series of facilities joined by a high-performance freight network.

5.2 Effects on Supply Chain

5.2.1 Effect on cost to develop and operate warehouses and DCs

The variety of distribution facility profiles, especially toward the urban core, indicates a range of solutions to situating inventory and speeding delivery. Facilities of different types and functions are used in combination. The real estate firm CBRE estimates that multi-story warehouse rents may be double or triple single-story rents[36] - yet because the multi-story designs are new and few, and because automation is growing, some of the associated costs can be expected to come down. Moreover, the urban infill challenge is being met with creativity: for example, an underutilized parking garage in downtown Chicago is being partially converted to an e-commerce staging facility, with semi-trucks unloading at ground level and smaller delivery vehicles handling product on higher stories.[37] These approaches lead to a spectrum of costs and trade-offs, and the choices will change over time. A low-cost cross-dock may suffice today provided it supports adequate service to the supply chain's market; the same calculation may shift as the underlying factors change.

A key consideration in this trade-off was emphasized by developer and retail representatives at an Urban Land Institute presentation in New York City in July, 2018. Their point was that, in today's market, service is overriding cost because companies cannot compete at lower service levels. "Service" equates to time to market: rapid delivery of a broad range of goods. This is another outgrowth of e-commerce pressures, and it means that the types of choices companies will make today is different than they have traditionally. Urban infill at urban prices may be a matter of survival, and be treated as an unavoidable cost of doing business.

5.2.2 Effect on locations of warehousing/DC clusters

The direct consequence is that urban locations clearly are becoming more competitive: the real estate cost is higher per acre, but throughput per acre can be increased, and the total burden to the business may be lower once the opportunity cost of lost sales and market share is taken into account. The warehousing stock in New York City mostly is half a century old[38] and ripe for redevelopment for a new class of demand. Multi-story designs, innovative adaptations, shared facilities and cross-docking are alternative ways to manage costs without forfeiting market position.

[35] NAIOP, ibid.

[36] "Multistory Warehouses Come with High Cost, Operational Burdens", Bisnow Boston, 12/18.

[37] Urban Land Institute, ibid.

[38] "Prologis has built the nation's first multi-level warehouse. Will the tenants come?", JLL quoted in Freightwaves, 11/18.

The demand for large DCs in New Jersey and Pennsylvania to serve to NYMTC market is not abating. As the foregoing discussion makes clear, businesses are adding warehouses, not substituting them; growth is occurring for large and small facilities; and the emerging model is multi-stage distribution responding to new needs for urban infill, met in multiple ways.

5.2.3 Higher freight generation per acre

Multi-story DCs bring a substantial increase in freight generation per acre, to the point of tripling in a three-story design. Automation has a comparable effect, one that could be felt more in NYMTC territory as costs decline. Cross-docks have high volume profiles because they are intended as fast truck-to-truck transfers. Shared facilities have higher generation rates because they enable greater utilization of the space, and therefore more total activity.

Equally significant is the proliferation and penetration of DCs into metro areas. Three boroughs of New York City are now slated for vertical warehouses. Acreage that had little or no freight generation will now acquire it –- and this is in addition to the growth of residential neighborhoods as generators of inbound freight through home delivery.

5.3 Approximate Timing of the Effects

The timing for these changes is now. The large peripheral facilities, the adaptation of infill facilities, and the arrival of multi-story DCs are visible in the NYMTC regional market today. The question is how big the shift will be, and for how long. This is tied to the growth of e-commerce and rapid home delivery, both of which are apt to get considerably larger over at least ten years. Or, as one security analyst put it, we are seeing great disruption while Amazon has less than 10% of the retail market. What happens if it reaches 30%?

6.0 Distributed Manufacturing

6.1 Trends

6.1.1 Description of products manufactured

Distributed manufacturing refers to the potential for three-dimensional (3D) printing to permit efficient production of goods near the points of demand, leading to many small factories situated in and serving many local markets. This contrasts with the long-standing imperative for factories to achieve economies of scale through mass production, and to locate large plants in limited numbers where the availability of raw materials, affordable skilled labor, vendors, or other factors of production make the achievement most efficient. Shipments to the NYMTC market of large volumes from some external sites in the U.S. or abroad, might be replaced by local shipments from points of production inside the NYMTC region. What products could be affected, to what degree, and how soon?

3D printing is a type of additive manufacturing (AM) by which products are formed by layering materials, as opposed to subtractive (cutting away) or formative (molding) techniques (AM and 3D are terms used interchangeably, although technically the latter is a category of the former). The 3D production machinery is loosely referred to as "printers" and does include inkjet printers used with ceramics and concrete, although they are just one of a half dozen types. Similarly, the raw materials may be referred to metaphorically as "inks"; the actual materials include plastics, metals and even food in various forms. Fused Deposition Modeling of plastics is the most common and probably best known production method, utilizing melted filaments extruded through a nozzle. The main methods, input materials, and applications are summarized[39] in Figure 6.1.

[39] "Additive manufacturing (3D printing): A review of materials, methods, applications and challenges"; Ngo, Kashani, Imbalzano, Nguyen, and Hui; Elsevier Journal – Composites Part B, 2018.

Figure 6.1 Methods, Materials, and Applications of AM

Methods	Materials	Applications
Fused deposition modelling	Continues filaments of thermoplastic polymers Continuous fibre-reinforced polymers	Rapid prototyping Toys advanced composite parts
Powder bed fusion (SLS, SLM, 3DP)	Compacted fine powders Metals, alloys and limited polymers (SLS or SLM) ceramic and polymers (3DP)	Biomedical Electronics Aerospace Lightweight structures (lattices) Heat exchangers
Inkjet printing and contour crafting	A concentrated dispersion of particles in a liquid (ink or paste) Ceramic, concrete and soil	Biomedical Large structures Buildings
Stereolithography	A resin with photo-active monomers Hybrid polymer-ceramics	Biomedical Prototyping
Direct energy deposition	Metals and alloys in the form of powder or wire Ceramics and polymers	Aerospace Retrofitting Repair Cladding Biomedical
Laminated object manufacturing	Polymer composites Ceramics Paper Metal-filled tapes Metal rolls	Paper manufacturing Foundry industries Electronics Smart structures

Source: Elsevier Journal (Ngo, Kashani, Imbalzano, Nguyen, and Hui)

3D printers are operated from software containing the design specifications. The specifications can be modified by changing the code, and different models can be produced simply by tweaking values or swapping in another design. This has tremendous benefits because it nearly eliminates set-up time and costs, which in turn permits a) faster cycles for new product introduction; and b) cost-effective production of a greater variety of goods.

The key advantages[40] of 3D as a manufacturing method are:

[40] Ngo, Kashani, Imbalzano, Nguyen, and Hui; ibid.

- Freedom of design, meaning the contours of products are less constrained by the production technique;
- Mass customization, signifying the ability to tailor production to local needs and individual tastes without loss of efficiency;
- Fast prototyping, stemming from the same virtues that enable mass customization: because production is controlled by software, it is readily changed, and supports small batches;
- Minimization of waste, e.g., by comparison to subtractive techniques, wherein much input material is cut away; and,
- Ability to manufacture complex designs, such as delicate lattices used in medical applications.

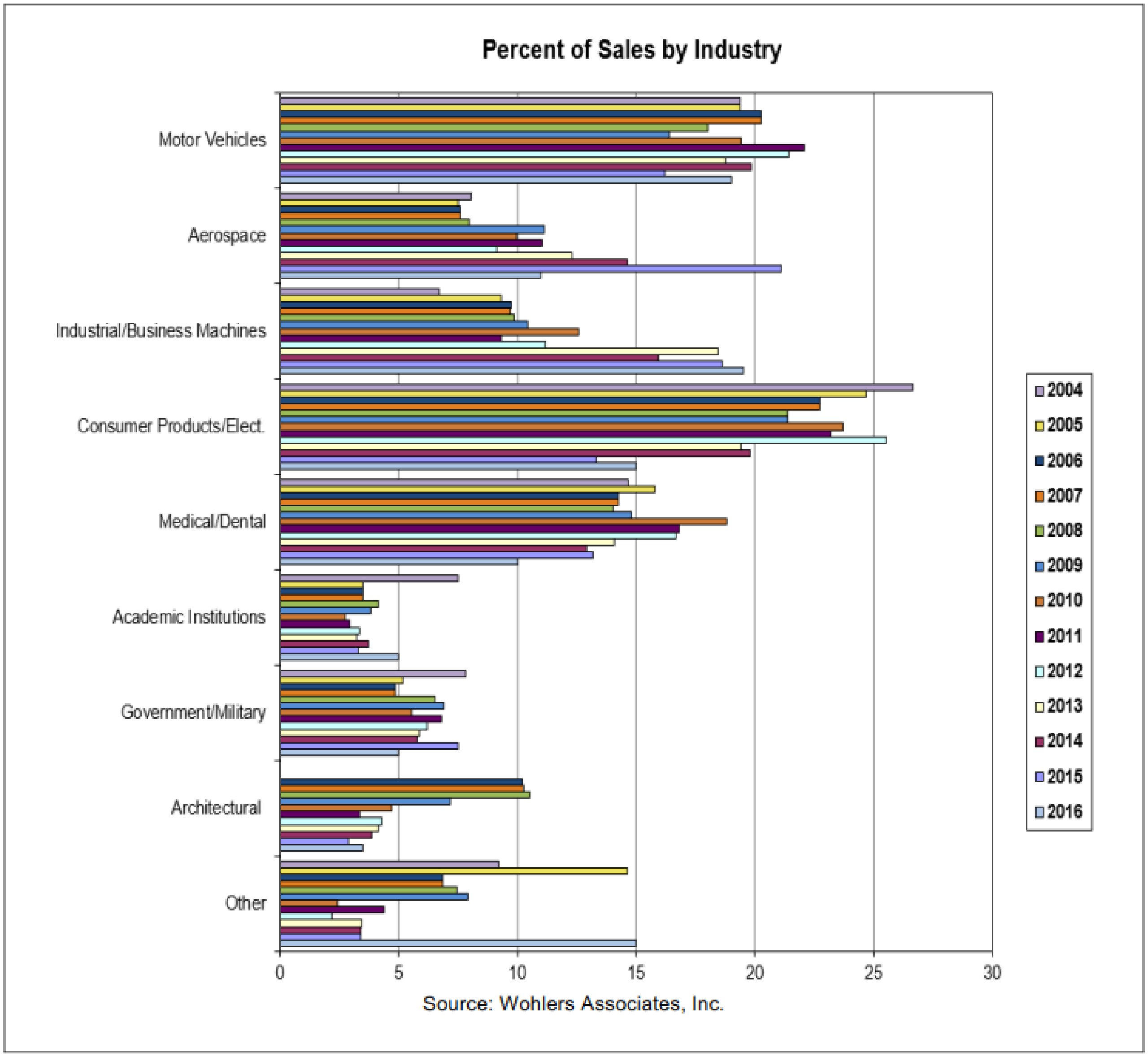
The size of the AM industry was $7.3 billion worldwide in 2017, growing 17 percent over 2016[41] and forecast[42] to grow at a compound annual rate of 15.2 percent in the five years through 2023. This industry size estimate reflects sales of printers and services, both industrial and "desktop" models, and excludes internal investments in processes and other equipment by the purchasers. At least as important, the estimate does not indicate the proportion of manufacturing processes converted to 3D methods. When the 3D printer market is compared to the $13 trillion in economic activity from global manufacturing, its small size understates its significance because it is a radically different form of production.

This consideration is important as well in interpreting the trends in purchases of printers by industry sector. While sustained or growing investment is clearly meaningful, declines may be due to temporary saturation, suggesting that an industry may have made most of the technology changeover that it currently can, and not that the role of AM is diminishing. Consumer electronics, medical devices such as hearing aids, aircraft components, footwear and toys are examples of product types. In the automotive sector, the entirely 3D-printed automobiles of Local Motors are a dramatic example, yet more meaningful is the industry's examination of opportunities to substitute 3D methods in suitable – but not all - segments of its overall manufacturing process. As with any commercial product, the question is not what is feasible for 3D manufacture but how it can contribute to goods that will sell: Local Motors is making small, niche vehicles and is not making high quality SUVs in volume.

[41] Wohlers Report 2018, Wohlers Associates, quoted in Forbes, 6/18.

[42] "3D Printing Market 2018", Wiseguy Reports, 9/18.

Figure 6.2 3D Printer Sales Trends by Industry Sector



6.1.2 Use in parts and sub-assemblies

The foregoing discussion highlights another crucial consideration in understanding 3D: it is not primarily about stand-alone machinery for fabricating entire products. Instead, it is a flexible and sometimes superior technique for improving production of components within existing manufacturing processes, reducing costs and making factories more competitive. Because of its benefits, companies in many sectors have been parsing their product manufacturing steps for elements that can be advantageously printed: intermediates, original and replacement parts, subassemblies. The actual producers of components may be the company's suppliers, within or outside the U.S. This reevaluation of methods also can lead to the introduction of new product features because of 3D's freedom of design, and ultimately lead to new formats for how and where factories operate. 3D machinery blended with robotics could substantially reduce labor costs, countering one of the principal motivations for offshored manufacturing.

The distinction between goods entirely versus partially printed has implications for the NYMTC region. Simple plastic items like some toys could be made anywhere, including in the home. Replacement parts for products ranging from automobiles and lawn mowers to laptops and home appliances also could be generated locally. Replacement parts are characterized by large variety (because products in use have been purchased over many years and versions) and low volume, a profile that aligns well with the capabilities of 3D printing. Parts warehouses and their inbound shipping could be replaced by printing sites, perhaps serving several industries. Conversely, factories that assemble complex products from numerous parts are unlikely to move to multiple locations. Even so, location decisions for new plants could be affected by reduced labor content, perhaps making markets like New York - with high cost labor yet large local demand -a more attractive option than it has been. The critical point is that AM changes the economics of factories. Distributed manufacturing in the sense of finished goods produced everywhere has a limited outlook today, but distributed production of components and different calculations for assembly plant siting foretell a shift in the geography of manufacturing.

6.1.3 Projections on market penetration and new technologies

The growth rates cited above imply that the size of the 3D market will double within five years. Impressive as that seems, the technology is early in its evolution, and there are considerable benefits and drawbacks to AM across the major material types used in industrial applications. The challenges are substantive; they include poor mechanical properties or adhesion of layers, inaccurate dimensions, post-processing requirements that add to cost, and a limited selection of compatible materials by comparison to conventional techniques. Defects that bar it from wider application are being addressed, and experimentation with new materials is ongoing. Research and development are continuing in academic circles and in industry; as it progresses, the viable uses of AM expand.

Figure 6.3 Materials, Applications, Benefits, and Challenges for AM

A summary of main applications, benefits and challenges of the main materials for additive manufacturing.

Materials	Main applications	Benefits	Challenges
Metals and alloys	Aerospace and Automotive Military Biomedical	Multifunctional optimisation Mass-customisation Reduced material waste Fewer assembly components Possibility to repair damaged or worn metal parts	Limited selection of alloys Dimensional inaccuracy and poor surface finish Post-processing may be required (machining, heat treatment or chemical etching)
Polymers and composites	Aerospace and Automotive Sports Medical Architecture Toys Biomedical	Fast prototyping Cost-effective Complex structures Mass-customisation	Weak mechanical properties Limited selection of polymers and reinforcements Anisotropic mechanical properties (especially in fibre-reinforced composites)
Ceramics	Biomedical Aerospace and Automotive Chemical industries	Controlling porosity of lattices Printing complex structures and scaffolds for human body organs Reduced fabrication time A better control on composition and microstructure	Limited selection of 3D-printable ceramics Dimensional inaccuracy and poor surface finish Post-processing (e.g. sintering) may be required
Concrete	Infrastructure and construction	Mass-customisation No need for formwork Less labour required especially useful in harsh environment and for space construction	Layer-by-layer appearance Anisotropic mechanical properties Poor inter-layer adhesion Difficulties in upscaling to larger buildings Limited number of printing methods and tailored concrete mixture design

Source: Elsevier Journal (N/go, Kashani, Imbalzano, Nguyen, and Hui)

Figure 6.4 Concrete Slab from 3D Printer

Source: Elsevier Journal (Ngo, Kashani, Imbalzano, Nguyen, and Hui)

Concrete products are a case in point. A variation on inkjet printing called contour crafting can create concrete shapes such as shown in Figure 6.4, yet the production challenges – notably the adhesion of layers – are significant. Workable techniques are still being invented. Simple dwellings have been 3D printed overseas from other materials; as concrete becomes practicable, the types of printable structures become greater, and add another industry where local production seems to make sense.

A different factor in growth projections is the effect of trade disputes on manufacturing location, and the ability of AM to provide an alternative. This is explored further below.

6.2 Effects on Supply Chain

6.2.1 Locations of production and distribution networks

Basic 3D printing capacity is generally available. A network of desktop models (defined as costing less than $5,000) was launched by UPS in 2016, in a joint venture with the enterprise software systems company SAP and the 3D printing specialists Fast Radius. The network originally had 60 UPS store locations, including two in the NYMTC Planning Area (and none in New Jersey), plus industrial grade equipment at the UPS national air hub in Louisville, KY. The network in 2019 has reduced to 31 locations, with one in NYMTC territory (and still none in New Jersey), although office stores like Staples also offer printers. Nevertheless, the objective of the UPS joint venture was to stimulate technology adoption by facilitating experimentation and prototyping, and to position UPS as a production partner with built-in logistical capabilities. Industrial grade printers placed in UPS truck terminals would be a natural further step if the market demand developed, with replacement parts offering a reasonable set of applications wherever volumes are thin and delivery service is important.

Dedicated 3D manufacturing requires industrial printers purchased by producers, whether for higher volume components or for integration into a larger manufacturing process. The scale of the factory can be smaller, depending on the other tooling required, because of the versatility of the technology. This helps in urban locations with expensive real estate. The deeper question is the business strategy companies employ to exploit the virtues of AM. A recent business journal[43] laid out six strategic models, most of them variations on the theme of products with specialized appeal, generated in mass. One type of strategic leverage the models make possible is contending with the supply and distribution advantages of entrenched competitors, and reducing supply and distribution risks. This is acutely pertinent today because of widening trade disputes coupled with higher ocean shipping costs, the latter resulting from the International Maritime Organization (IMO) mandate[44] for low sulfur fuels effective in 2020. Supply chain managers are rethinking their sourcing in the face of this, and could rethink their production methods. Concurrently, the management consultants AT Kearney[45] argue that the intrinsic advantages of 3D and its offsetting of lower foreign production costs could on-shore to United States manufacturing $330-500 billion in import product value in five sectors: automotive, aerospace, consumer products, healthcare and medical devices, and general industrials. This would reflect 3D penetration claiming between 23 and 40 percent of production in these sectors over the next ten years.

There is no clear way to isolate the locations in the NYMTC region where new production may occur. Food, healthcare products, and construction materials are affected industries active in the territory, but metropolitan New York is a massive consumer market with continuing demand for replacement parts as well as finished goods. Industries that can serve it effectively from a local base will try to, whether fabrication occurs in New York, New Jersey, or farther out. Moreover, 3D is a disruptive technology, implying that new business models will come to the fore and supplant some of the old products and patterns of supply.

One activity very likely to be affected is imports through the sea and airports, because of the factors discussed above. Not only could this happen soon, it could accelerate 3D adoption around the country, precipitating further geographic shifts. Neither are declining imports apt to be replaced by exports, since the drivers of change are localized models of production affecting both sides of the ocean, as well as higher transportation costs.

6.2.2 Printing Materials Supply

The inks used in 3D processes are numerous and specialized, since they must be compatible with methods to render them in fluid state. Figure 6.4 above reviews the materials, their forms, and the types of printer they supply. Many of them are heavy (e.g., metals, ceramics, concrete) and might be suitable for bulk transport as demand grows, although some sort of protective packaging seems likely in many cases. One possibility is the development of local depots that break down bulks into consumable bundles for regional delivery, in addition to direct deliveries in volume to factories.

The sources of inks are not well defined, because they are specialty items thus far. Presumably the industries that produce plastics, metals, ceramics and other inputs will be able to serve the new and growing demand, although from which plants in which states remains to be seen.

[43] "The 3-D Printing Playbook", Richard D'Aveni, Tuck School, Harvard Business Review, 7-8/18.

[44] Coalition for Responsible Transportation presentation to U.S. Dept. of Commerce, 10/18.

[45] "3D Printing and the Future of the US Economy", AT Kearney, 2017.

6.2.3 Commodity mix

In addition to the inks just described, the commodities affected by 3D production will be a mix of intermediate goods (such as parts) and finished goods. Which ones are produced in the NYMTC area will determine the demand for inks. Inbound products serving the regional population seem the most probable to be shifted, although outbound goods may be affected. For example, specialty foods such as chocolate and some baked goods are existing applications of 3D printing; NYMTC area producers may adopt it while continuing to ship to external markets as well as locally.

Based on the types of goods now in play, the prospects for on-shoring and the demand from population, the commodity groups affected should include:

- Healthcare and medical products
- Footwear
- Sporting goods
- Specialty foods
- Construction materials
- Parts for transportation equipment & appliances
- Electronic components
- Toys
- Ceramic housewares
- Chemical products

6.2.4 Modal utilization

There are three overarching considerations for assessing the effect of 3D on the utilization of freight modes. First, to the extent that businesses adopt 3D for the sake of truly distributed manufacturing, then local production will be intended for local consumption and will replace inbound goods from external sources. Second, to the extent that 3D is adopted as an integrated element in a larger manufacturing process to secure competitive advantage, then factories may serve large geographic areas, including national and global markets. Third, to the extent that total delivered costs are lower through domestic 3D manufacturing than through overseas production, then domestic will replace foreign origination. With these points in mind, the anticipated modal effects are:

- **Truck:** motor carriage will handle local and regional delivery of products. Compared to today when some of those products move from around the nation and world, there will be less modal diversity in affected supply chains. Trucks also will be important for delivery of inks, especially where volumes are small, or producers are regional, or for intermodal drayage.

- **Rail:** rail will be viable for containerized transport of inks, and potentially for carload transport of inks in bulk. At least one of the Class I railroads in NYMTC territory has targeted the market for inks. Carriage of goods produced by integrated factories shipping longer distances will continue to be modally competitive, especially for intermodal transport. However, rail traffic in marine containers is likely to decline.

- **Marine:** seaports are apt to face losses of containerized trade, at least in terms of market share for some classes of goods, and probably in terms of absolute volume. Inks could grow as import or export commodities, but whether they simply replace movements of the same material in other forms (such as metallic inks replacing metal shapes) is an open question.

- **Air:** overseas traffic is likely to be hurt. Domestic traffic would decline for goods transferred to local production. However, 3D is an imperfect process today, suggesting a need to fly replacements for defective products while the technology evolves. The role of air freight as the fail-safe system for supply chain breakdowns and disruption should remain intact.

6.3 Approximate Timing of the Effects

AM is an actively evolving technology: in printers, materials, applications, and in accumulated experience of its use for the fabrication of goods. It makes a decidedly minor contribution to manufacturing processes today, yet its contribution is larger for some goods, and its use is growing rapidly. Adoption is stimulated by delivered cost advantages for local, domestic production versus overseas sourcing. Adoption could be accelerated by the risks to trade brought on by tariff policies and the International Maritime Organization (IMO) fuel mandate.

In sum, the course of development should play out over ten to twenty years. However, the growth curve could become steeper as soon as 2020 because of trade factors, and material effects could be observed then. In the event of a new recession, the demand for goods would drop while the business need for competitive advantage would rise. Recession thus could create another stimulus for adoption of 3D technology, with the volume effects not felt until economic recovery began.

7.0 Conclusions and Effect on the Regional Freight Plan

7.1 Expected Effects of the Trends on Supply Chain Logistics

With five key trends identified, and varying levels of intensity with which each could take hold and shape goods movement over the forecast horizon, there is a seemingly limitless number of potential future scenarios. It is reasonable, however, to assume that all of these trends will continue to evolve and shape global supply chains and local distribution over the forecast period, and that the effect of these continued trends will be a future that is not "business as usual." Table 7.1 summarizes the effects of the trends described in this memorandum on supply chains, generally. If these trends continue, the future could be a world in which the relative cost of transporting goods from overseas is higher, the cost of long-haul domestic moves is lower (after accounting for investments in automated technology and equipment), and the cost of last-mile deliveries increases, in order to meet consumers' demands for ever higher levels of service.

All of the trends analyzed indicate that movement of goods by truck will remain essential, especially for last-mile movements in large consumer markets, such as the NYMTC planning area. And the relative cost of long-haul trucking could improve the competitive position of that mode, relative to rail intermodal, for many long-distance domestic moves of consumer goods in the long-term. Rail intermodal will likely continue to be a desirable mode for moving international containers, and rail carload and domestic water will be a desirable mode for growing volumes of construction materials and products that will be inputs for 3D printing.

The expected growth in E-commerce and warehouse automation suggest rising demand for warehousing and distribution centers within, or very close to, major population centers, such as New York City. As historic trends have favored warehouse and distribution center development in locations where land and development costs are lower, such as suburban and exurban New Jersey and Pennsylvania, the need to meet increasing consumer demand for next-day, same-day, and same-hour delivery will necessitate development of more logistics centers in the five boroughs and immediate surrounding areas.

Figure 7.1 Effect of Trends on Supply Chain Logistics

		E-Commerce	Less-Than-Truckload (LTL)	Vehicle Automation	Warehouse Design and Automation	Distributed Manufacturing
Trends		• Increasing Direct-to-Consumer (D2C) shipments; • Increasing demand for fast, reliable (and "free") delivery.	• Growth, fueled by Ecommerce D2C; • Superior labor pool compared to TL.	• Truck "driver assist" features being deployed now, pilot-tests of platoon and automated trucks for long-haul applications underway • Automated delivery vehicles are being developed • Automated trains in operation overseas, some interest among US freight railroads • Positive Train Control (PTC) improves safe rail operation • Marine terminals have (and will continue to develop/advance) automated data systems. Significant automation retrofits at most East Coast ports (including NY/NJ) seem unlikely in the foreseeable future.	• Demand for faster time to market is driving growth in multi-stage distribution; • Automation controls inventory and maximizes throughput; • Value of being near consumers helps to overcome high cost of urban industrial space, and supports urban infill.	• Significant traction in manufacturing parts and sub-assemblies; • Uses plastics, resins, concrete, etc. today, but experimentation with new materials can expand input commodity mix.
Expected Supply Chain Effects	**Demand**	Increased consumer product (durable and nondurable) D2C demand.	Growing demand for products moved by LTL.	Reduction in operating costs could lead to lower product pricing and greater demand for goods.	Supports growing demand for D2C shipments; Automated DCs can generate greater volumes of freight per acre than traditional DCs.	Could increase demand for "raw" materials, while shortening supply chain (which would show up as decreased travel demand in freight models) for finished goods made by AM/3D.
	Modes	Growing air cargo volume, LTL truck, cargo van, innovative last-mile delivery modes.	Truck with trailer size ranging from 28' to 33'.	Automation is occurring across all modes (in one form or another). If autonomous trucks become ubiquitous, trucks could become more cost-competitve for longer-distance shipments.	Large "regional" DCs are receiving inbound TL, outbound is mostly TL; Smaller DCs near population centers receive inbound TL and generate outbound LTL.	Movement of "raw materials" by rail could replace some long-haul movement of finished consumer goods by truck.
	Origins and Destinat	Fulfillment centers located as close to population centers as possible.	Most growth in metropolitan areas, facilitating D2C, last-mile, etc.	Effects of automation on location decisions remain unclear.	Urban locations are becoming more competitive.	Could lead to on-shoring of manufacturing for some products.
	Logistics Cost	Higher cost per ton than traditional ship-to-store.	Higher cost per ton than TL.	Automation involves an initial large investment in capital and technology systems, but in some cases can lead to a significant reduction in operating and labor costs.	Service is overriding cost. Costs of automated, urban DCs are high, but necessary to provide level of service desired.	Reduced transportation costs could offset the cost of moving production closer to consumption, resulting in a net decrease in cost.
	Timing	Growth likely to slow over time. Many unknowns in long-term, but team's reasonable estimate is growth from 10% of retail sales in 2018 to just over 40% by 2045.	Largely tied to the ecommerce and warehousing trends. Expect growth in last-mile LTL through forecast period.	Short-term, more "assist" features; Platooning and autonomous trucks deployed in short-term, to assume significant roles in mid-to-long term.	These changes are happening now, and will continue in the near term.	Rapid growth in near term, further growth into the 2030s would depend upon evolution of technology and relationship between production and transportation costs.

7.2 Expected Effects of the Trends on Regional Freight Plan Recommendations

The trends and their anticipated effects on freight and logistics, as described above, indicate effects on the relative importance or urgency of recommendations in the Regional Freight Plan. The recommended actions in the Regional Freight Plan are divided into four categories:

- Planning initiatives, which may study a wide variety of alternatives;
- Project planning and/or environmental reviews for vision projects;
- Programmed improvement projects; and
- Policies or programs that advance desired outcomes and address needs.

In addition, these trends and effects may suggest new opportunities that were not considered previously. The new opportunities are proactive approaches NYMTC member agencies can do to not only anticipate global trends, but to ensure that the NYMTC Planning Area is at the forefront of innovation, and helping to shape the trends going forward. This section describes these effects and opportunities applicable to each of the four categories.

7.2.1 Planning Initiatives

Planning initiatives include studies, likely to be initiated and completed in the near term, that could lead to the identification of future programmed projects to be implemented in the long term. These studies should anticipate the longer-term effects of the trends described in this memorandum, including the possibility that E-commerce could represent 40 percent of retail sales, potentially broad deployments of automation technology in freight vehicles and warehousing, and clusters of distribution and 3D manufacturing facilities are developed in various parts of the planning area.

These considerations should be applied to planning initiatives across the board, but with greater emphasis on improvements and solutions that address truck safety, delivery and last-mile issues (including efficient delivery and environmental impact), and industrial land use. Land use considerations should include E-commerce and 3D/distributive manufacturing location needs, where industrial lands that meet those industries' needs are available and/or in need of preservation/protection from encroachment and development, etc.

The effects of the trends analyzed in this document, as well as recent news of the vast expansion of tech companies in the New York area, including investments by technology leaders Amazon and Google, suggest a potential opportunity for the region's transportation agencies to partner with tech companies who have a footprint in this region, to pilot-test last-mile delivery innovations, autonomous vehicles, and technologies for monitoring travel patterns. Partnerships between public agencies and tech companies have yielded interesting and sometimes successful tests of solutions in a number of U.S. and international cities.

7.2.2 Project Planning and/or Environmental Reviews

Project planning and environmental reviews are performed to evaluate and screen alternatives, leading to the development of projects that could be completed in the near, medium, or long term horizons. Consideration of how the trends are likely to impact modal utilization (i.e., the balance between truck, rail, and water), industry location decisions, and operating characteristics during the project's respective planning horizon. Project planning and environmental review initiatives in the Regional Freight Plan that support highway, rail, and marine infrastructure improvements should consider the potential for the improvement to serve growing and evolving industry demand, in response to the trends analyzed in this document, and trends that will emerge hereafter.

7.2.3 Programmed Improvement Projects

Programmed improvement projects include capital investments already prioritized in the Transportation Improvement Program or the Regional Transportation Plan, *Plan 2045*. Many of these projects will be implemented in time to experience near-term expected effects of the trends, while some are on longer timelines.

Many of the near-term projects are preservation and safety projects, which are needed to maintain and improve the safe movement of freight on the region's transportation network. These projects are needed regardless of the outcomes of the trends. However, economic development and transportation access projects included in the Regional Freight Plan can leverage economic development strategies to support or proactively market E-commerce and/or 3D/additive manufacturing companies. As traditional and/or autonomous truck and delivery vehicles, marine, and rail demand grow in response to economic and population growth and the trends explored in this memorandum, the investments listed in the Regional Freight Plan will facilitate efficient goods movement.

7.2.4 Policies and Programs

Policies and programs include initiatives to improve rail and marine access, facilitate "freight village" style industrial development, monitor truck activity, and address potential community and environmental impacts associated with goods movement. Key relationships between the trends and improvements and solutions in this category include:

- The potential for automated delivery, especially using electric vehicles designed for heightened pedestrian and bicyclist safety, to be well-integrated into cities and communities. Automated delivery could also address some of the personnel and security issues that are cited by some business establishments who have been reluctant to try off-peak deliveries, thus accelerating participation in that initiative.

- The movement of raw materials for 3D printing/distributed manufacturing could, in the medium to long term, boost demand for water and rail shipments into various parts of the region. This would place greater emphasis on dredging and rail access programs.

- Urban logistics center and freight village strategies could be adapted to meet the needs of E-commerce, LTL and automated delivery, and 3D/distributed manufacturing.

In addition, as discussed in Section 4.2, advancements in automation of trucking, rail equipment, and marine terminals pose both the opportunity to improve communication and collision avoidance, while also introducing potential conflict during "transition" periods, when level 3-5 automated and traditional equipment could be sharing infrastructure. A wide range of stakeholders will have to provide input into policies that govern infrastructure design, traffic operations, and emergency and first response (e.g., should first responders have the capability to control AVs in an emergency situation?).

Analyses in this category of improvements and solutions also offer the region's transportation agencies the opportunity to evaluate and demonstrate the viability of urban logistics centers for E-commerce, where higher land values and development costs are acceptable in exchange for being closer to consumers and able to meet ever-increasing consumer demands for quick and reliable delivery.

In the near-term, 3D/distributed manufacturing will continue expanding into different product categories. Because 3D/distributed manufacturing could be disruptive to the warehousing and logistics sectors, which are big industry sectors in the NYMTC Planning Area and neighboring New Jersey and eastern Pennsylvania, this region should prepare Proactively market industrial land, brownfields, makerspaces, etc. as opportunity sites for 3D/distributed manufacturing, with the advantage of being located close to the point of consumption, in the nation's largest consumer market.