

TECHNOLOGY AT WORK v3.0

Automating e-Commerce from Click to Pick to Door

Citi GPS: Global Perspectives & Solutions

August 2017



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TECHNOLOGY AT WORK v3.0

Automating e-Commerce From Click to Pick to Door

Our Technology at Work series serves to highlight the implications of the disruption brought by the digital revolution. As we have shown in previous reports, 47% of jobs in the United States are at risk of automation over the forthcoming decades and similar shares have been estimated for other countries. This means the effects of the digital revolution are yet to be seen. In a recent interview in April 2017, Jack Ma, founder and Chairman of Alibaba, expects “decades of pain” as the Internet disrupts traditional businesses leading to “all sorts of industries and walks of life.”

This report, the third in the Technology at Work series, focuses on the automation driven by e-Commerce for physical goods. We look at the technology needed to automate order fulfillment, inventory management, and delivery when consumers shop online and examine the implications in a wide range of areas for industry, retailers, supply chains, real-estate, and transportation, looking too at the impact on labor and employment.

Growth in e-Commerce is the main driver of warehouse automation, a driver which itself will increase with broadband and mobile device penetration. In Japan, 32% of all goods bought on the Internet were bought on smartphones in 2016, up from 27% a year earlier. Millennials, those most likely to shop online, will soon enter their peak spending years. Global e-Commerce sales have grown at a compound annual growth rate of 20% over the last decade, and online retail sales have gone from ~2% of total to ~8%.

While technology is not yet either capable or cost effective in all cases, this is likely to change. Our estimates show that that 80% of jobs in transportation, warehousing, and logistics are susceptible to automation as a consequence of the trends we observe in technology. Retail is one industry in which employment is likely to vanish, but unlike manufacturing jobs which are highly concentrated, the downfall of retail employment will affect every city and region. U.S. companies employ 2 million people just to do stock and order fulfillment work and over 90% of warehouse picking is currently done by hand. Migrating to automated picking gives productivity gains of 2x–3x that as compared to pick-to-conveyor operations and 5x–6x as compared to manual pick-to-pallet fulfillment centers.

The adoption of technology is by no means uniform. While one-hour delivery is available when buying online in some parts of the U.S. and Europe, the average promised delivery time in Brazil is nine days. While e-Commerce penetration is 87% in the U.K., it is only 18% in Romania. By end industry, penetration is highest in clothing and sporting goods.

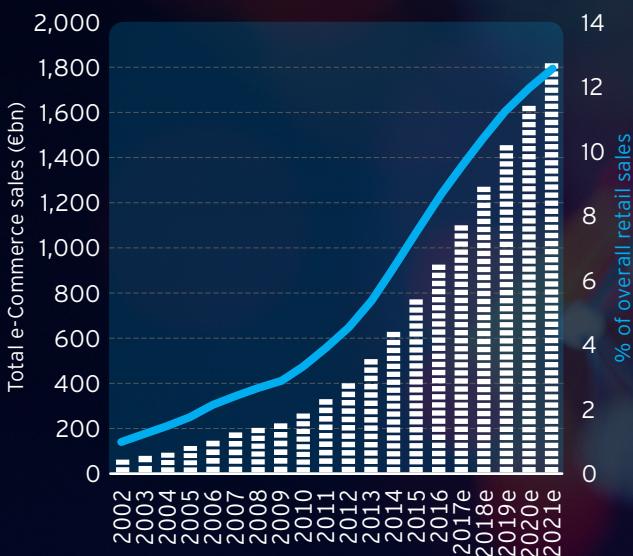
The virtual world is also subject to physical constraints. Warehouse availability is now at an all-time low in the U.S. and land availability for warehouses is already a problem in London, where 60%–70% of industrial sites sold are “lost” to residential development. Online business models need 300% more warehousing space compared to store-based fulfillment. Based on forecasts from Euromonitor for global e-Commerce growth, over 2.3 billion square feet of new warehousing space will be required by 2035. Road traffic is a challenge too — kilometers traveled by light goods vehicles in the U.K. were 47% higher in 2015 compared to 2000, while kilometers traveled by passenger cars were only 5% higher.

Much of the Technology Disruption is Yet to Come

In the last decade retail sales transacted online have gone from ~2% of total to ~8%, yet penetration of automation remains quite low. e-Commerce penetration varies greatly by country, and as millennials enter peak spending years the e-Commerce driver will increase, meaning that much of the disruption from automation in transport, warehousing, and logistics is yet to come.

Total e-Commerce Sales and % of Overall Sales

Source: Euromonitor International



Online Grocery Penetration

Source: Citi Research, Kantar

South Korea	10.0%
Japan	7.2%
U.K.	6.9%
France	5.3%
Taiwan	5.2%
China	4.2%
Czech Republic	2.1%
Netherlands	1.7%
Spain	1.7%
U.S.	1.4%
Portugal	1.0%
Belgium	0.9%
Italy	0.4%
Brazil	0.1%



PRODUCTIVITY INCREASES SHOULD DRIVE AUTOMATION PENETRATION...

Warehouse picking is currently >90% manual but automated picking can be 5-6x more productive.

Companies like Amazon are increasing the number of robots in the fulfillment centers.

Source: Citi Research, Company reports

	Number of Robot Enabled Fulfillment Centers at Amazon	Avg # of Robots per Fulfillment Center
Sep 2013	3	461
Dec 2014	10	1500
Dec 2015	13	2308
Dec 2016	20	2250
Jun 2017	25	3200

...AND INCREASED AUTOMATION WILL PUT A LARGE NUMBER OF JOBS AT RISK



of jobs in transportation, warehousing, and logistics and...

of jobs in sales are susceptible to automation.

LOCATION, LOCATION, LOCATION



Online business models need **300%** more warehousing space as compared to store-based fulfillment

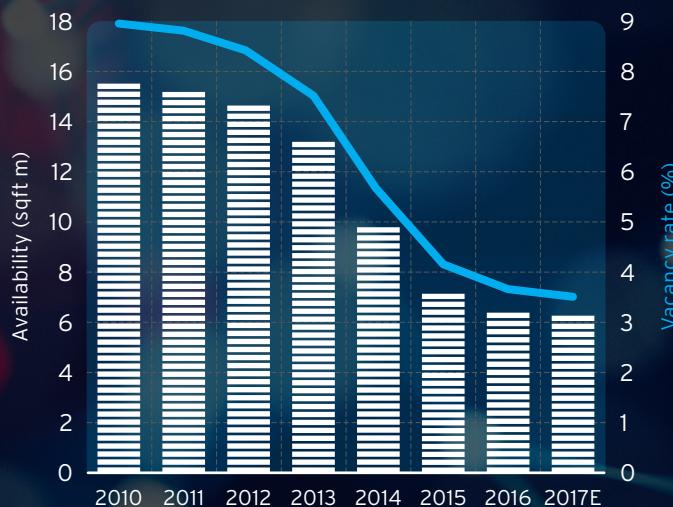


Over **2.3 billion** square feet of new warehousing space will be required by 2035

But...warehouse availability is now at an all-time low in the U.S. and **60-70%** of industrial sites sold in London are "lost" to residential development

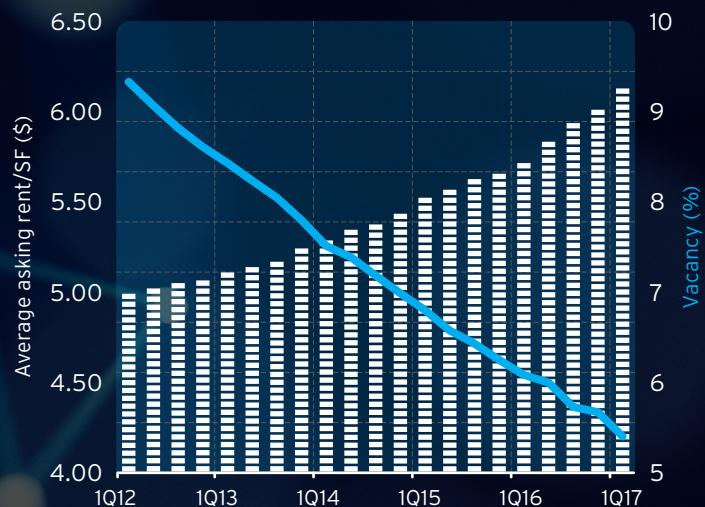
London Industrial Availability (Floor Space)

Source: Colliers International



U.S. Industrial Asking Rent and Vacancy

Source: NGKF



About the Oxford Martin School

The Oxford Martin School at the University of Oxford is a world-leading centre of pioneering research that addresses global challenges.

The School invests in research that cuts across disciplines to tackle a wide range of issues including climate change, disease, cyber threats, and inequality. The School supports novel, high risk, and multidisciplinary projects that may not fit within conventional funding channels, but which could dramatically improve the wellbeing of this and future generations.

Established in 2005 through the generosity and vision of Dr. James Martin, the School provides academics with the time, space, and means to work collaboratively and to engage policymakers, business people, and the general public. To qualify for School support, the research must be of the highest academic caliber, tackle issues of a global scale, have a real impact beyond academia, and not be able to have been undertaken without the School's support. All research teams are based within the University of Oxford. In the School's first decade, more than 500 researchers have worked on 45 research programmes, from ageing to vaccines.

For more information, please visit www.oxfordmartin.ox.ac.uk.



About the Oxford Martin Programme on Technology and Employment

The Oxford Martin Programme on Technology and Employment is a research programme established in January 2015 with support from Citi. It has been created to investigate the implications of a rapidly changing technological landscape for economies and societies. The programme will provide an in-depth understanding of how technology is transforming the economy, to help leaders create a successful transition into new ways of working in the 21st century. The programme is part of a wider research partnership between the Oxford Martin School and Citi, analyzing some of the most pressing global challenges of the 21st Century.

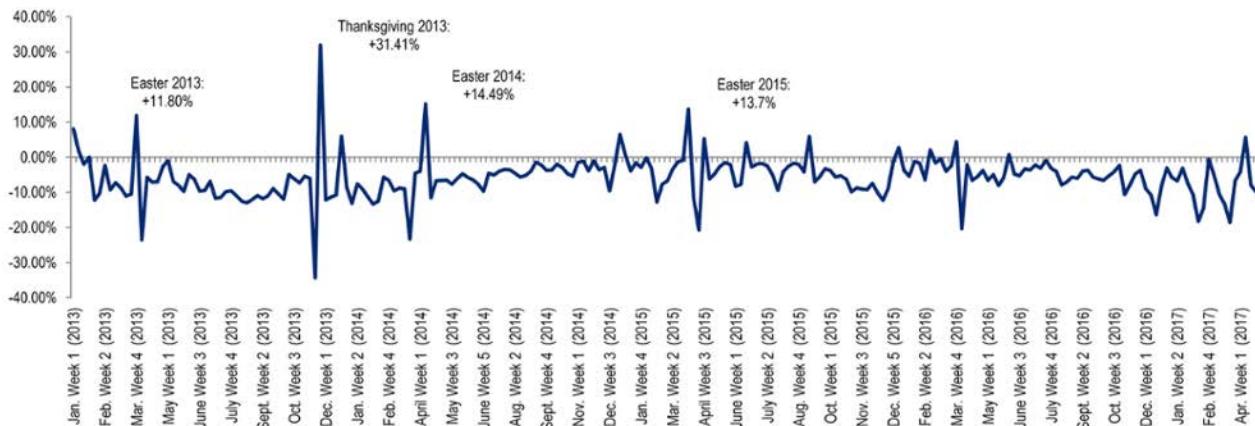
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Key Points

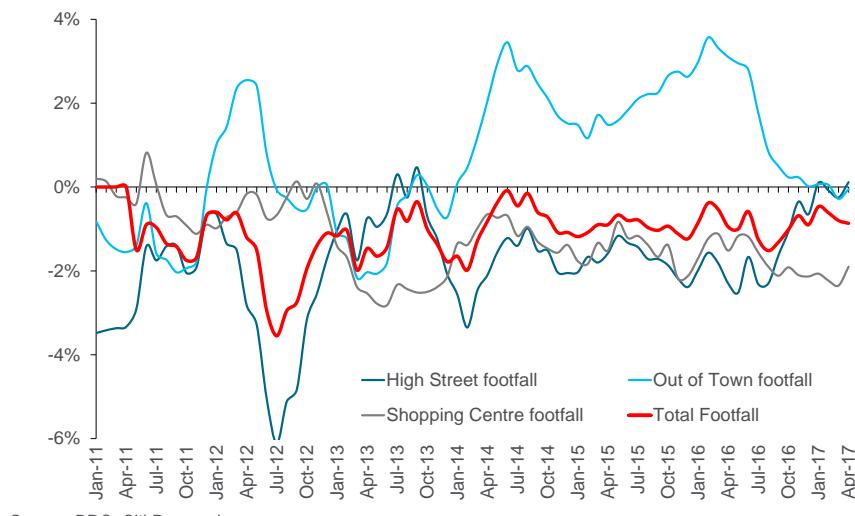
- **Much of the technology disruption is yet to come:** While e-Commerce is growing at double-digit annual rates, automation penetration remains quite low in many cases. Technology is not yet either capable or cost effective in all cases of order fulfillment, meaning that labor shortages are, for now, still a major pinch point. Technological progress in sensors, data, and software are as important as that in robots and drones to enable this automation. Some of this technology is only just now reaching commercial potential (and some is still on the drawing board), meaning that the full impact of technology has yet to be felt. Even the demand-driver of e-Commerce itself will increase with broadband and mobile device penetration.
- **Jobs in transport, warehousing, and logistics have above-average susceptibility to automation:** Our estimates show that 80% of jobs in transportation, warehousing, and logistics are susceptible to automation, as a result of recent technological developments and another 63% of sales occupations, higher in both cases than the 47% of total jobs that are potentially automatable in the United States.
- **Growth in e-Commerce is the main driver of warehouse automation:** This driver itself will increase with broadband and mobile device penetration. The driver of e-Commerce growth will always be the "pull" from the consumer. In this report we look at the online penetration of retail by category and geography to understand why there are different levels of development and then look at what has driven the growth of e-Commerce. We then look at the implications for the retail sector, how retailers are adapting to cope with e-Commerce, and ultimately what impact further automation may have on the retail landscape.
- **Cross-border e-Commerce looks set to stay, further driving warehouse demand:** Warehouse options range from one central hub globally to fully localized fulfillment. DHL estimates that 15% of e-Commerce is cross-border, and is set to increase to 25%, as the cost of carrying inventory has to be balanced against the cost of shipping cross-border. There is also a broader debate on the location of manufacturing when factories (and not just fulfillment and delivery) are fully automated. The CEO of Adidas commented in April 2017 that large-scale reshoring of manufacturing jobs from Asia back to the west is a "complete illusion" due to entrenched supply chains in Asia. Citi economists highlighted in a January 2017 report the physical goods where China has the largest comparative advantage of production as compared to the U.S. were footwear and apparel & clothing accessories – categories that are also amongst the most popular for online purchases.
- **Real estate will be impacted in two ways:** First, is the already-visible decline of high street and mall footprints (or the need for them to fill with other experiential offerings), but second is in how the need for warehouses near or in dense urban areas is changing how planners look at zoning land. We examine some emerging innovations and concepts that have the potential to significantly impact real estate markets, from the integration of industrial and residential land uses in significantly land-constrained markets, to the development of vertical warehouse solutions and even towards flexible warehouse solutions along the lines of AirBnB.

Figure 1. Shoppertrak Traffic: Physical Mall Footfall Continues to Weaken as Consumers Increasingly Shop Online...



Source: Shoppertrak, Citi U.S. Consumer Research

Figure 2. U.K. Footfall Has Been in Constant Decline Since Early 2011



Source: BRC, Citi Research

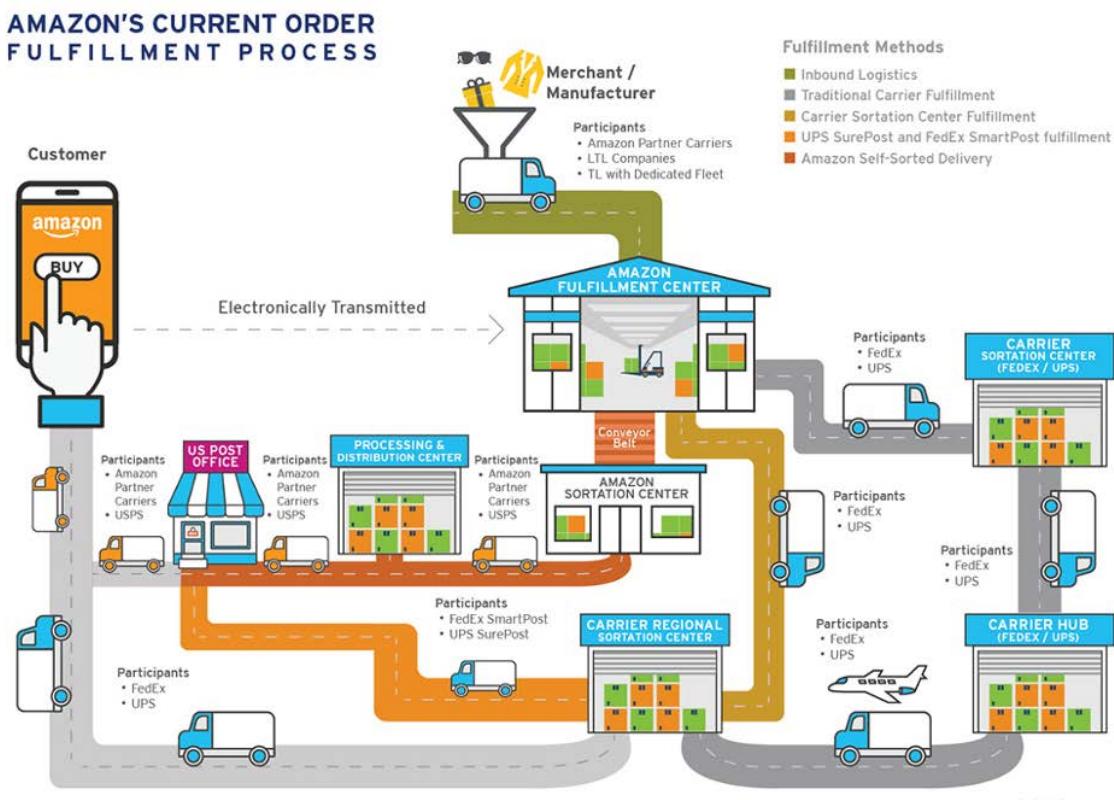
e-Commerce Is the Key Driver of Automated Fulfillment

e-Commerce is predominantly serviced by centralized warehouses or distribution centers. Due to the large amount of stock held in each location compared to traditional store-based retail, the efficient handling of inventory is more important in e-Commerce. The need for automation in warehouses from e-Commerce can be traced to shorter order cycles, a high level of returns (which need storing), and the need to increase SKU (stock keeping unit) availability.

- **e-Commerce continues to outpace offline sales:** Total e-Commerce sales in the U.S. totaled almost \$395 billion in 2016, up over 15% year-on-year and accounting for 8.1% of retail sales. In the U.K., Internet sales as a percentage of retail have now reached 15.3%, or well over 23% if considering only non-food items. In Japan, the Ministry of Economic, Trade & Industry (METI) estimates that in 2016, the total value of Business-to-Consumer (B2C) electronic commerce rose 10% YoY to ¥15.1 trillion (~\$138 billion), with the electronic commerce market accounting for 5.43% of total commercial transactions, up from 4.75% in 2015.

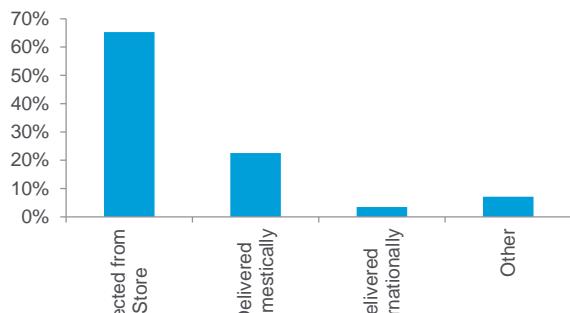
- Once customers start shopping online, they start to do more purchases online: For the first time in 2016, respondents to a United Parcel Service (UPS) survey of online shoppers stated that on average just over half of their purchases were made online.
- Delivery is crucial to e-Commerce success: In 2016, Amazon Prime Now customers in certain parts of the U.K. could order Christmas gifts up until 9.45pm on Christmas Eve with one-hour delivery by 10.45pm. A 2016 report by Eurostat indicated “speed of delivery being slower than indicated” being the most common issue for those customers that encountered a problem while buying online.
- Millennials — the most likely to buy online — are entering peak spending years: According to Eurostat, individuals aged between 25 and 34 make the highest proportion of their purchases online. As this cohort enters its peak spending years — commonly defined as 45 to 54 — this should further drive online sales.
- Broadband penetration a key enabler of e-Commerce, and a precursor to automation: The e-Commerce experience just isn't the same over a dial-up connection. In Japan, in 2016, METI says that smartphones were used to buy 32% of all goods bought on the Internet, up from 27% a year earlier.

Figure 3. The Amazon Fulfillment Process



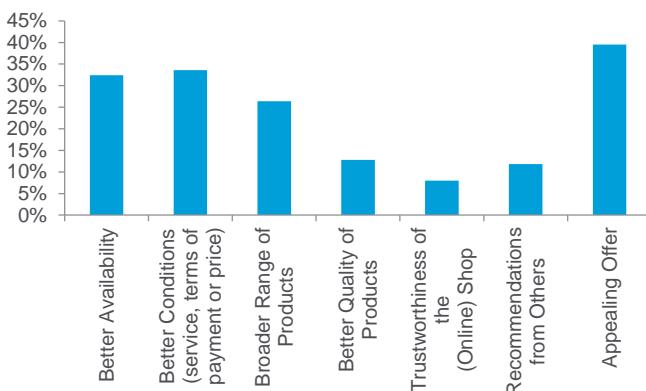
Source: Citi Research

Figure 4. In Europe Store Collection Is Still the Most Common Way of Retrieving Purchased Goods...



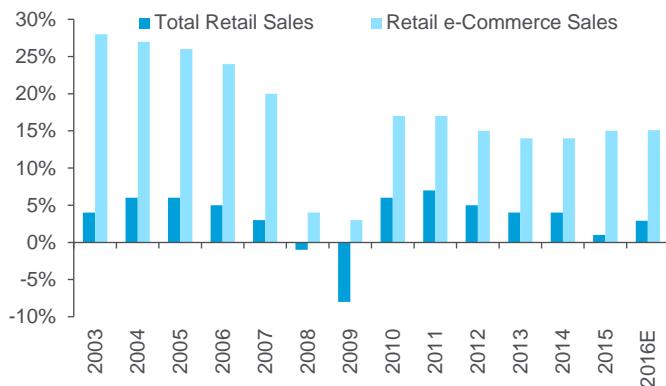
Source: Google Barometer (figures represent EU average)

Figure 5. The Reason Consumers Buy Products Overseas Is Mainly Due to Attractive Offerings and Better Availability...



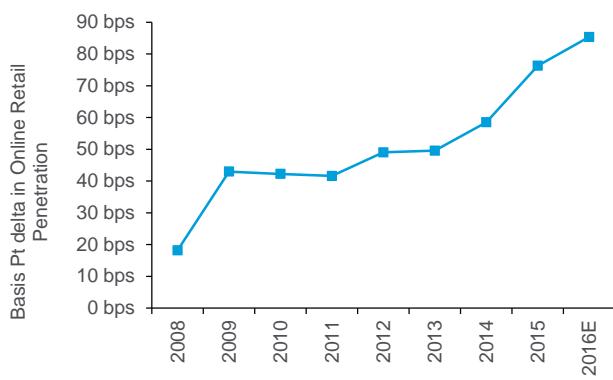
Source: Google Barometer, (figures represent EU average)

Figure 6. U.S. Online Retail Sales and Online Share of Total Retail Have Been Steadily Rising for Years



Source: U.S. Department of Commerce, Citi Research (figures in US\$bn, LHS)

Figure 7. In Fact, e-Commerce Share Gains Are Actually Accelerating



Source: U.S. Department of Commerce, Citi Research

Total e-Commerce sales in the U.S. totaled almost \$395 billion in 2016, up over 15% year on year and accounting for 8.1% of retail sales

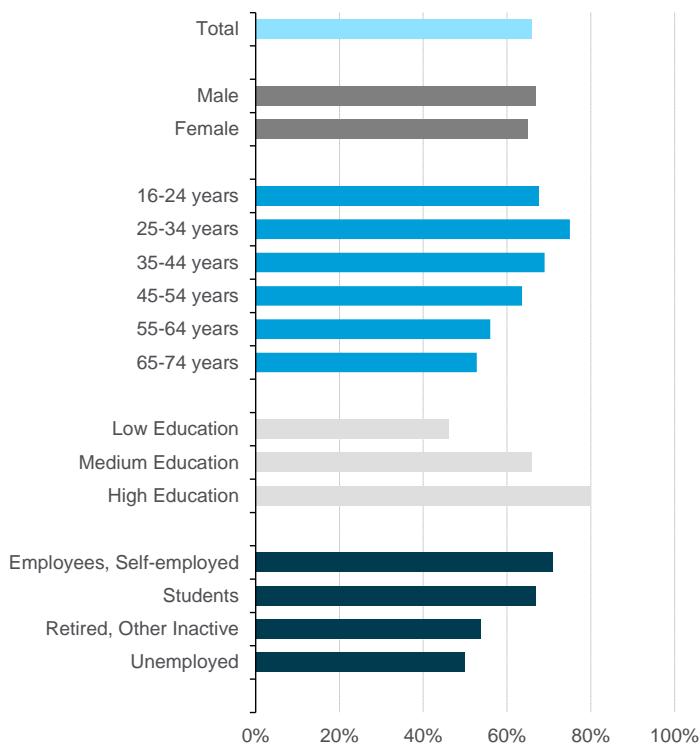
Figure 8. U.S. Total Retail and Retail e-Commerce Sales Growth



Source: U.S. Department of Commerce, Citi Research

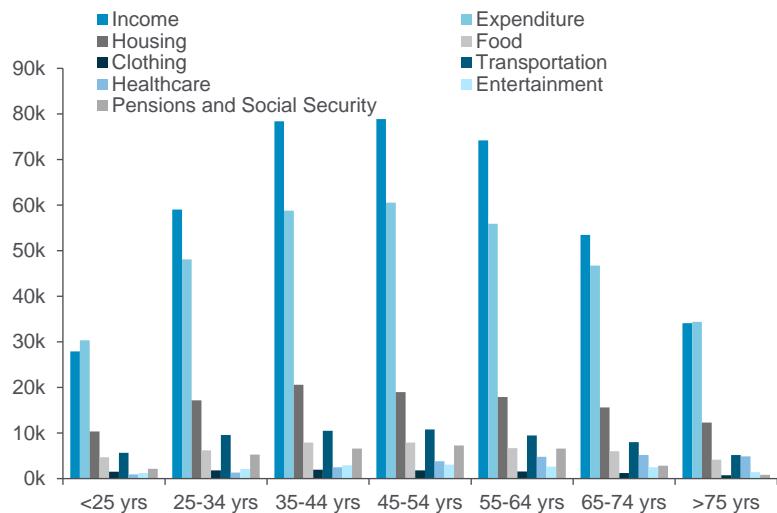
There are enormous differences by region. In the European Union (EU), Eurostat estimates that 87% of Internet users in the United Kingdom bought goods or services online in 2016, compared to only 18% in Romania. Demographic cohorts matter too, with 25–34 year olds most likely to buy online according to Eurostat. As this cohort enters its peak spending years, e-Commerce growth looks set to continue.

Figure 9. Individuals Between 25–34 Years of Age Show the Largest Proportion of Purchases Done Through the Internet



Source: Eurostat

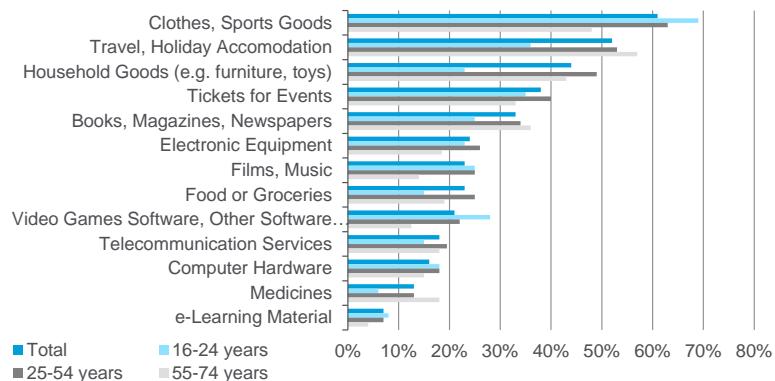
Figure 10. Consumer Spending by Category and Age Groups



Source: BLS.gov, Citi Research

Penetration also varies by category: Clothing and sports goods are the most common category for online purchases. As the demand for these goods increases, the implication is that retailers in this space would benefit the most and have the greatest need for the automation of fulfillment.

Figure 11. Online Purchases by Segment



Source: Eurostat, Citi Research

Consumer Preferences

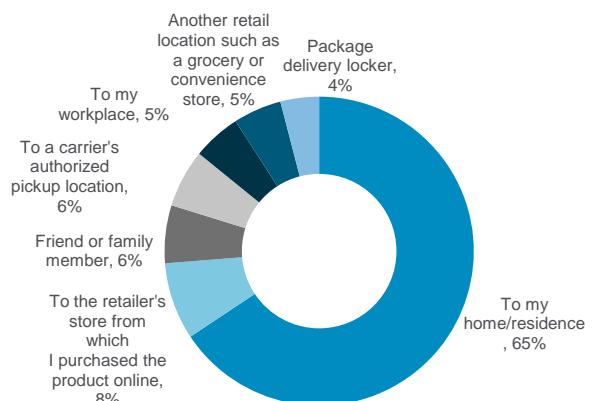
UPS' annual Pulse of the Online Shopper Survey shows that for 42% of online purchases bypass the store completely (search online, buy online) and the vast majority (92%) of deliveries also bypass the store (in contrast to Europe, as shown in Figure 13).

Figure 12. Frequency of Purchases by Method in the U.S.



Source: UPS

Figure 13. The Reason Consumers Buy Products Outside the U.S. is Mainly Due to Attractive Offerings and Better Availability...

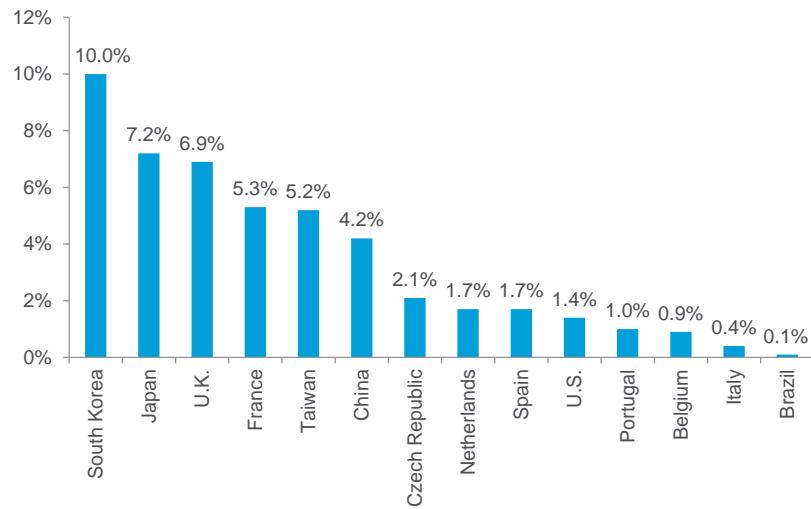


Source: UPS

Asia's e-Commerce Penetration

On the global stage, four of the top six penetrations for online grocery are in Asian countries, commensurate with the higher levels of overall retail penetration in countries such as South Korea and Japan.

Figure 14. Asia Has Four of the Top Six Countries for Online Grocery Penetration



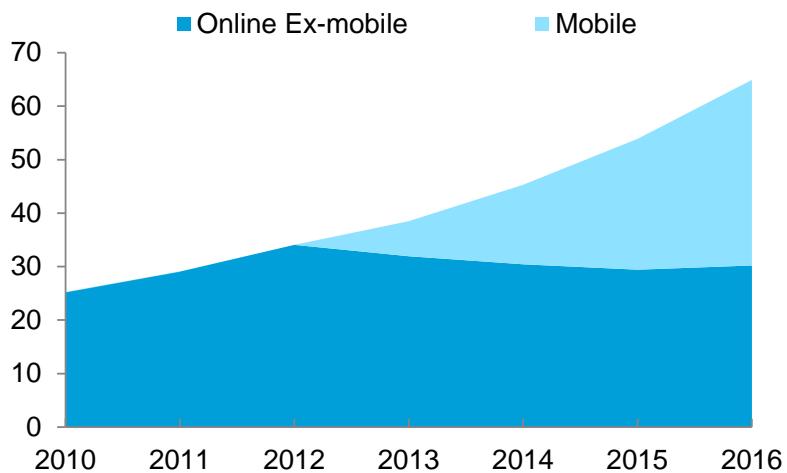
Source: Citi Research, Kantar, Korea Statistics Office (Note: market share of FMCG e-Commerce)

Korea's e-Commerce Market

Korea's online shopping market takes up around 15% of overall retail revenues, with more than half of this being done via mobile. Mobile shopping sales have grown at a significant compound annual growth rate of over 70% since 2013, with shopping products ranging from electronics and apparel to groceries.

Despite the prevalence of e-Commerce in the market, Korean retailers have relied on heavily manual logistics, with automation in the warehouse space only a recent phenomenon. One of Korea's leading retailers, E-Mart, recently launched a newly automated warehouse, 'NE.O', capable of handling 10,000 orders per day with 20,000 SKUs, although a good proportion of the overall handling process such as picking and sorting is still heavily manual.

Figure 15. Korean Online Shopping Is Switching to Mobile



Source: Citi Research, Korea Statistics Office

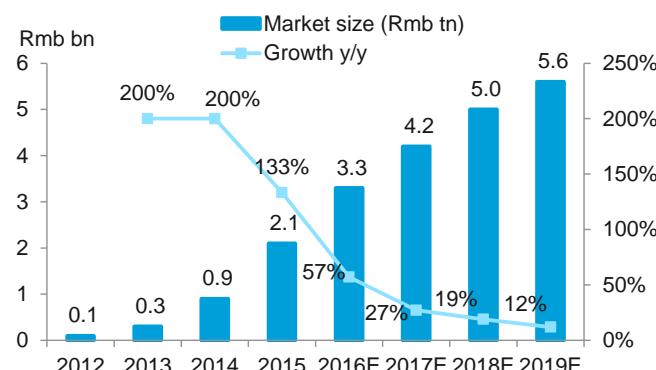
Note: figures in KRW tn

China e-Commerce Market Overview

In China, the online penetration of the retail market is growing fast. With monthly retail data growing fairly steady at around 10%–11% year-over-year for every month over the past two years, we forecast a rapid growth of the online retail market. According to the National Bureau of Statistics' latest data, online retail sales in the first half of 2017 amounted to Rmb3.2 trillion (\$350 billion), up 33.4% year over year and equivalent to an 18% online penetration rate.

In particular, according to iResearch, the size of the China mobile shopping market in 2016 was Rmb3.3 billion (\$495 million), up 57% year-over-year and accounted for 63% of China's total e-Commerce market. In terms of market landscape, the mobile e-Commerce market is dominated by Alibaba and JD.com, which accounted for 80.5% and 13.4% of the market respectively in the first quarter of 2017.

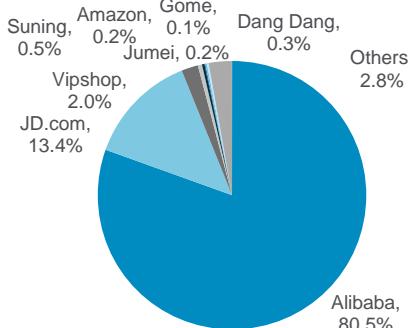
Figure 16. China Mobile Shopping Market Size and Growth Rate



*GMV = Gross Merchandise Value

Source: iResearch, Citi Research

Figure 17. China Mobile Shopping Market by GMV in 1Q17



Source: Analysys, Citi Research

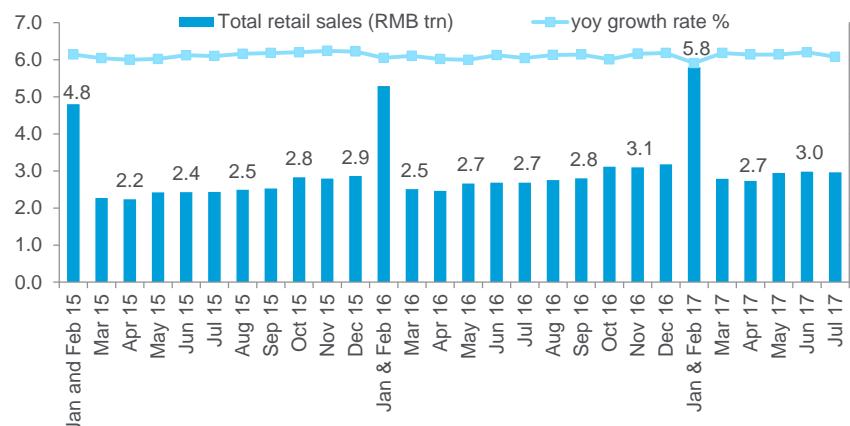
Figure 18. China E-Commerce Market Size and Breakdown

	2010	2011	2012	2013	2014	2015	2016	2017E	2018E	2019E
*Market size (Rmb tn)	0.5	0.8	1.2	1.9	2.9	4.1	5.2	5.7	6.6	7.5
YoY Growth (%)	75.3%	70.2%	51.3%	59.4%	46.9%	40.4%	28.5%	8.6%	15.8%	13.6%
As % of total retail sales	2.9%	4.3%	5.6%	8.0%	10.7%	13.6%	15.8%	15.6%	16.6%	17.6%
Business-to-Consumer (Rmb tn)	0.1	0.2	0.4	0.8	1.3	2.1	2.9	3.3	3.9	4.6
Consumer-to-Consumer (Rmb tn)	0.4	0.6	0.8	1.1	1.6	2.0	2.3	2.4	2.7	2.9
% of total market										
Business-to-Consumer	13.7%	25.3%	34.6%	40.4%	45.1%	52.1%	55.3%	57.9%	59.7%	61.0%
Consumer-to-Consumer	86.3%	74.7%	65.4%	59.6%	54.9%	47.9%	44.7%	42.1%	40.3%	39.0%
Breakdown of PC and mobile										
PC (Rmb tn)	0.5	0.8	1.1	1.6	2.0	2.0	1.9	1.5	1.6	1.9
Mobile (Rmb tn)	0.0	0.0	0.1	0.3	0.9	2.1	3.3	4.2	5.0	5.6
% of total market										
PC	99.5%	98.5%	91.6%	84.1%	69.1%	48.6%	37.1%	26.3%	24.2%	25.3%
Mobile	0.5%	1.5%	8.4%	15.9%	30.9%	51.4%	62.9%	73.7%	75.8%	74.7%

*Note: In terms of gross merchandise value

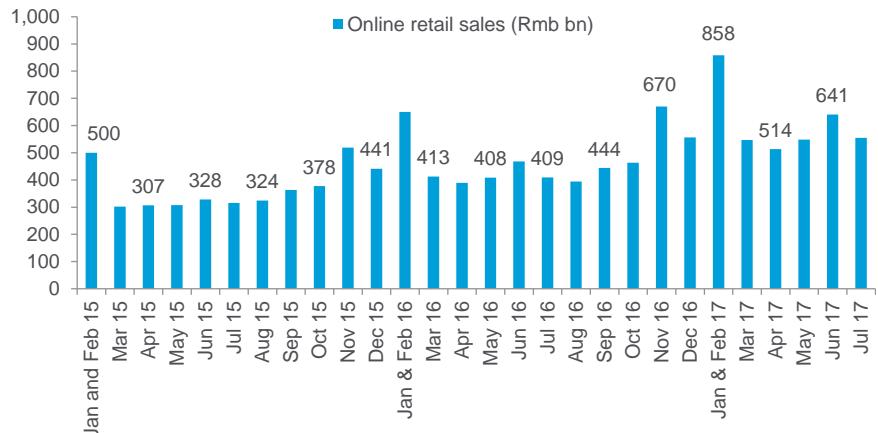
Source: NBS, iResearch, Citi Research

Figure 19. China Total Retail Sales



Source: NBS, Citi Research

Figure 20. China Online Retail Sales



Source: NBS, Citi Research

Latin America Still in the Early Stages of e-Commerce Developments

e-Commerce in Latin America is still in early stages of development, with penetration of online sales of roughly 2%.

Figure 21. e-Commerce in Latam and Brazil

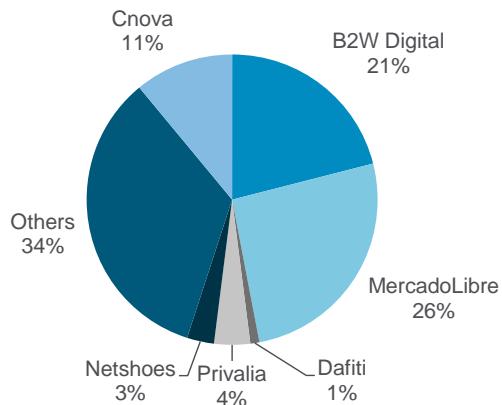
Retail e-Commerce % of total retail sales						
	2016	2017	2018	2019	2020	2021
Argentina	2.60%	3.10%	3.60%	4.00%	4.30%	4.60%
Brazil	1.60%	1.90%	2.30%	2.70%	2.90%	3.20%
Mexico	1.20%	1.40%	1.70%	2.00%	2.30%	2.60%
Other	1.70%	2.00%	2.30%	2.80%	3.00%	3.40%
Latin America	1.90%	2.20%	2.60%	3.00%	3.20%	3.50%

Digital buyer penetration (% of population)						
	2016	2017	2018	2019	2020	2021
Argentina	38.10%	39.90%	40.70%	41.20%	41.70%	42.00%
Brazil	27.70%	29.40%	30.90%	32.10%	33.20%	33.80%
Mexico	23.80%	26.20%	28.10%	29.90%	31.60%	32.90%
Other	33.50%	36.00%	38.40%	40.00%	41.50%	42.50%
Latin America	30.00%	32.20%	34.00%	35.40%	36.80%	37.70%

Source: eMarketer, December 2015

Brazil is the largest market in the region, with the most sizable population. Mercado Libre — a pure marketplace platform focused in Latin America — is the largest player in the region, followed by B2W, the online arm of a traditional brick-and-mortar retailer in Brazil.

Figure 22. MercadoLibre Is the Largest e-Commerce Player in Brazil...
Market share as a percentage of 2016 gross merchandise value



Source: E-bit, Company Reports, Citi Research. * MEI includes non-marketplace services.

The announcement that Amazon could be willing to make a more aggressive step in the region could re-shape the competitive landscape. Amazon entered Brazil in 2012, but has been dealing only in books so far.

In June 2017, an important newspaper in Brazil reported that Amazon will add categories such as smartphones, notebooks, tablets, and accessories in the coming months, and further fine-tune its logistics, before it then starts to offer a full product assortment in the country.

Given the overwhelming power of Amazon in its core markets, this raises the bar for local players. Amazon offers not only extremely high levels of service in several countries, but has the deep pockets to support a long period of investment until it consolidates its presence as a dominant player.

Drivers of e-Commerce in Latin America: Mobile Data Evolution

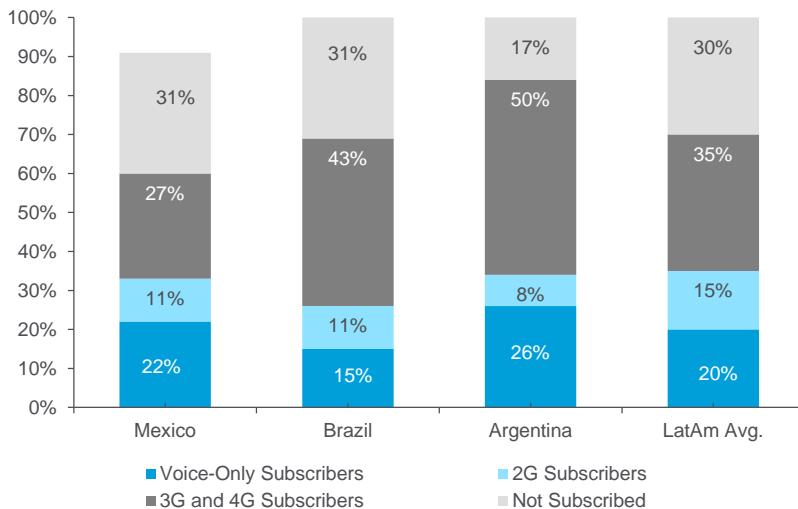
In Brazil, the penetration of broadband Internet is ~37%, but the mobile phone base is already more than 1 per inhabitant, with ~43% of the population being 3G or 4G subscribers.

Figure 23. Fixed Broadband Household Penetration in Select Countries, 2016

Country	% of Households
Canada	95%
U.S.	83%
Turkey	60%
Chile	59%
China	51%
Argentina	51%
Mexico	47%
Colombia	41%
Brazil	37%

Source: E-marketer, Instituto Federal de Telecomunicaciones (IFT) - Mexico and Ovum as cited in "Segundo Informe Trimestral Estadístico 2016," Oct 12, 2016

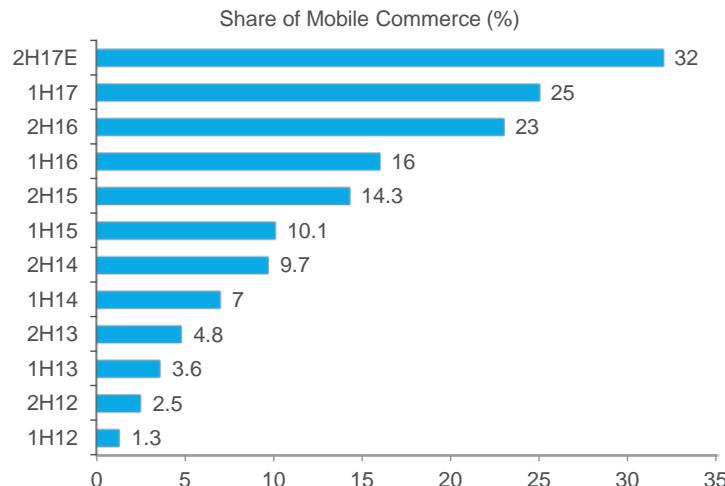
Figure 24. Subscribers % by Type



Source: GSMA Intelligence

About 25% of online sales in Brazil are already done through mobile phones (vs. 16% in 2016), and this should be an important growth driver for the e-Commerce segment, especially for that portion of the population which does not count on broadband Internet at home.

Figure 25. Mobile Commerce is Gaining Share in Brazil



Source: E-bit, Citi Research

According to the "Global Mobile Consumer Survey" published by Deloitte, 57% of Brazilians check messages from social media and other online channels on their smartphones in the first five minutes after they wake up and again before going to sleep. Being connected full time appears to be a necessity to a large part of the population.

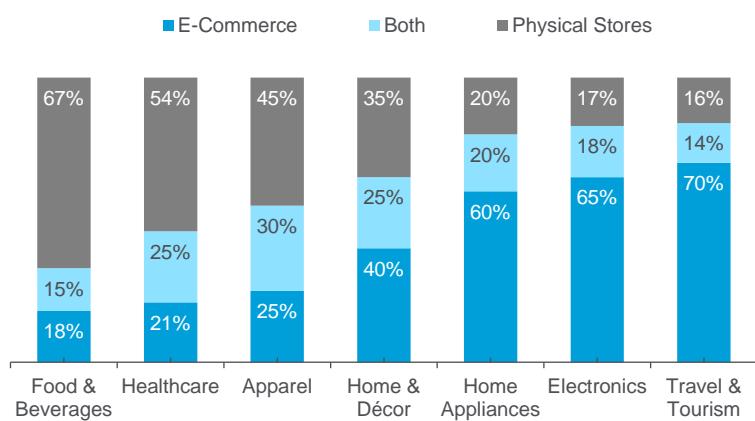
Those habits are also reflected in consumption, showing that more consumers are adopting online shopping habits, especially through mobile devices.

Logistics Is Still the Main Bottleneck in Brazil

Brazil is a continental country, and the limited reach of specialized delivery companies poses a huge challenge in logistics. There is no Brazilian equivalent to U.S. companies UPS or FedEx, making delivery slow and expensive. The average promised delivery time is ~9 days, and in most cases deliveries are still made through the post office ("Correios"). This long delivery period ends up driving shoppers to traditional brick-and-mortar retail stores, especially for more urgent purchases, for smaller items that won't require specialized delivery like heavy furniture, or for big home appliances like refrigerators.

So differently from the EU, in emerging markets like Brazil online sales are still concentrated on big-ticket items.

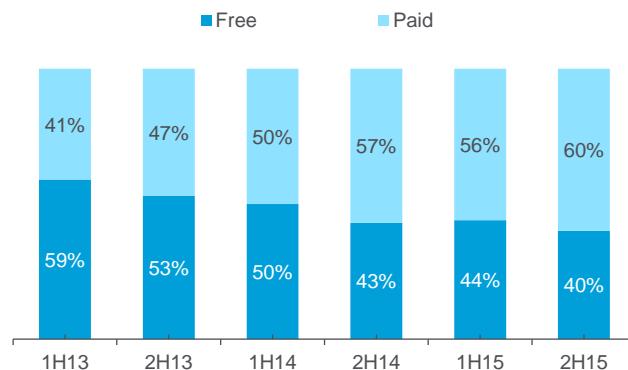
Figure 26. Brazilians Tend to Buy More Big-Ticket Categories Online...



Source: E-bit, Citi Research

Without the convenience effect of online purchase (e.g. in the U.S., Amazon offers same-day delivery in several regions of the country), pricing becomes one of the key drivers for the Brazilian market. So a strategy that many companies have adopted to mitigate this effect is to sponsor free shipping to attract buyers. While this practice has been decreasing, due to the obvious burden in profitability, it still represents 40% of online sales.

Figure 27. 40% of Online Sales Still Count on Free Shipping in Brazil
Free shipping vs. paid shipping as a percentage of total online sales



Source: E-bit, Citi Research

e-Commerce Players in Brazil are More Focused on an Omni-channel Strategy, than on Being Pure Online Players

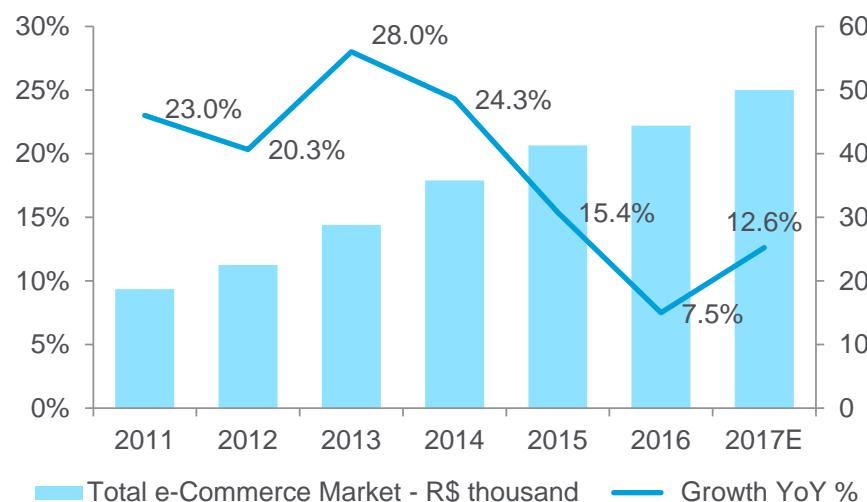
With the exception of MercadoLibre, which is a pure marketplace platform (operating through an asset light business model), all the other e-Commerce players in Brazil have a brick-and-mortar background. Lojas Americanas (the controlling shareholder of B2W), Via Varejo, and Magazine Luiza are some of the largest retailers dealing in electronics, home appliances, and mobile phones in the region.

Most of these companies started their online stores to leverage an 'omni-channel' strategy (one that provides a customer with a seamless, integrated shopping experience, including both online and brick-and-mortar choices), but very few actually have made money out of it. Pricing is still one of the main attributes driving online sales in Brazil, as the convenience factor usually tends to be eliminated by long delivery periods. This translates into a low-margin environment, worsened by huge working capital requirements, as most sales in Brazil are done in several installments.

In addition, most of these companies share their distribution centers with the ones already serving the physical stores in the group. So despite the growth in the online market, we're still not seeing growing prices for warehouses in Brazil, unlike other mature markets where online penetration is much higher.

Figure 28. Online Sales Are Expected to Grow 12% in 2017...

Online sales in Brazil, R\$ billions



Source: E-bit, Citi Research

Automation in Latin America

We believe that the apparel retailers in Latin America are the ones in more advanced stages in terms of automation in the region. Lojas Renner, one of the largest department stores in Brazil, invested in two distribution centers with automated picking and sorting per SKU. But this also comes as part of an omni-channel strategy, given that the online channel still represents less than 5% of the company's sales.

Data, Devices, and Sensors Continue to Be Enablers of Automation

The predecessor to this report, [Technology at Work](#), published in February 2015, found that 47% of U.S. jobs were at risk from automation, with advances in technology making a broader range of non-routine tasks automatable, with technology expected to substitute for low-income and low-skill workers over the coming decades.

The second report, [Technology at Work v2.0](#) also found that the expanding scope of automation mainly relates to advances in Machine Learning technology, including Data Mining, Machine Vision, Computational Statistics, and other sub-fields of Artificial Intelligence (AI), turning a wide range of knowledge work into well-defined problems. This is made possible by the provision of relevant data, including through connected devices, advances in user interfaces, and cheaper and better sensors are all drivers of the big data revolution.

The Industrial Internet has become possible through the ability to deploy vast numbers of remote sensors cheaply, with cloud computing enabling the storage of the vast amount of data then generated. Since the last Technology at Work report was published in January 2016, we'd note the following progress:

- **The ability to data mine in industrial applications has been substantially boosted by the falling cost of cloud computing and by recently launched industrial software on cloud platforms:** Citi's software research team recently estimated that cloud capabilities dramatically transform the cost structure of IT, noting that data storage can be up to 95% cheaper on the cloud. Several industrial cloud platforms, designed to gather and aggregate data in industrial applications, including GE's Predix and Siemens' Mindsphere, which saw their commercial launches during the course of 2016, and ABB's Ability which launched in early 2017. We estimate there are >300 industrial cloud platforms in various stages of commercialization.
- **The number of connected devices continues to grow:** The ability to add sensors and data gathering to any industrial device or manufactured product allows for information gathering previously unthinkable. The amount of data being generated is massive: According to Intel, a connected factory is estimated to generate 1 petabyte per day, the equivalent data of 1.05 billion minutes of MP3 songs, or data of 160 million books.
- **Progress in sensors and machine vision further enables warehouse automation:** We estimate that the sensors market is growing at ~10% annually. Cognex, a technology leader in the space of industrial machine vision, says the largest opportunity for its machine vision is in manufacturing, but it also notes there is growing demand for machine vision systems from companies looking to improve distribution and warehousing efficiencies. Its customer base is approximately one-third electronics and one-third automotive, with the next most important market said to be logistics.

When Will the Least Automatable Tasks Become Automatable?

The [Technology at Work](#) report also highlighted several skills that are the least automatable, highlighting examples in Originality (the ability to come up with unusual or clever ideas about a given topic or situation, or to develop creative ways to solve a problem), Service Orientation (actively looking for ways to help people), Manual Dexterity (the ability to quickly move your hand, your hand together with your arm, or your two hands to grasp, manipulate, or assemble objects) and Gross Body Coordination (the ability to coordinate the movement of your arms, legs, and torso together when the whole body is in motion). These are not binary definitions; with 67 variables per occupation, with each variable giving, for each occupation, an integer between 0 and 100, which quantifies the level at which a certain skill or ability is required. For example, for Manual Dexterity, a low level corresponds to "Screw a light bulb into a light socket" while a high level is described as "Perform open-heart surgery with surgical instruments". The variables are built from the O-NET US Department of Labor database.

These technological limitations still persists but not for want of trying. We note that in the above analysis the task to "pack oranges in crates as quickly as possible" was classified as requiring a medium level of dexterity, perhaps explaining why technology has yet to usurp the human hand on this one (for now at least). As we highlight later, the Amazon Robotics Challenge (formerly the Amazon Picking Challenge) exists to seek an answer to one of these issues that it is yet to solve: i.e. commercially viable automated picking in unstructured environments.

The CEO of Adidas highlights a similar (perhaps more difficult?) challenge: How to create a robot "*that puts laces in the shoe*", adding that it is "*a complete manual process today. There is no technology for that*".

Ocado, the online U.K. supermarket delivery chain, has recently been evaluating the feasibility of the "SoMa project," which explores the robotic picking and packing of shopping orders. Short for "Soft Manipulation," the project is a European Union funded program that aims to be fully implemented by 2020 and in collaboration with various research institutions across Europe. The project aims to develop a gripper compatible with existing industrial robot arms, but able to handle more fragile objects such as fruits and vegetables.

Critical Success Factors

Without Delivery, e-Commerce Is Nothing

"For e-Commerce firms, the three most important infrastructure items are information flow, cash flow and delivery"

Jack Ma

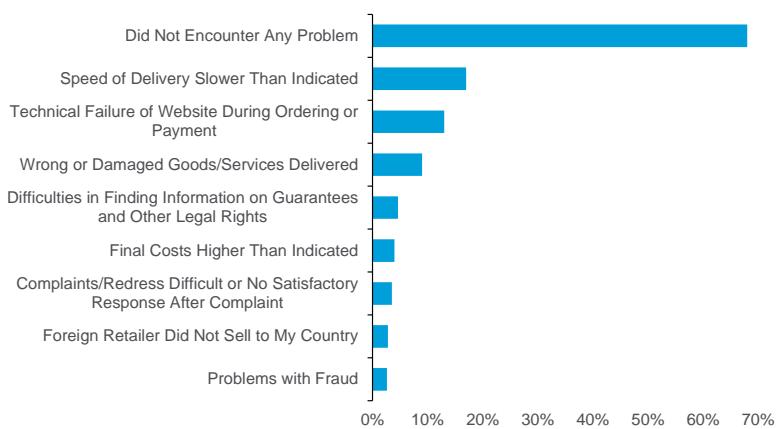
Jack Ma, Alibaba founder famously said in 2013 that *"For e-Commerce firms, the three most important infrastructure items are information flow, cash flow, and delivery."*

For retailers, Citi's U.S. retail team also recently highlighted "four factors to solving omni-channel" which we list below. The final three are essentially linked to the automation of inventories, order fulfillment, and delivery.

1. Seamless presentation between channels
2. Optimized and automated inventory management
3. Fulfillment process (pick and pack)
4. Transportation logistics

In Japan, there are widely reported problems afflicting trucking/delivery companies which are struggling to keep pace with the growing demand for small parcel deliveries. At the same time, they also face higher wage costs due to employee shortages. In the year to March 2018 Yamato Holdings plans to hire over 9,000 new workers, bringing their workforce more than 210,000, with more than half of the increase being part-timers (~116,000 total). The company says it wants “*to improve work conditions in the group at a time when the number of parcels is growing rapidly in line with the increasing popularity of online shopping.*” For the customers too, delivery matters. For e-Commerce customers citing a problem, speed of delivery was the most quoted example.

Figure 29. Problems Encountered When Buying on the Internet



Source: Eurostat

Developments in Delivery Technologies

Trucks stuck in traffic raise operating costs and waste fuel

A Smart City study by the U.S. Department of Transport (DoT) includes the aim to use technology for “*facilitating the movement of goods into and within a city.*” The DoT estimates that trucks stuck in traffic in U.S. metropolitan areas cost companies \$28 million annually in operating costs and wasted fuel. Potential solutions include installing signals that prioritize trucks along freight corridors and providing truckers with real-time information on parking availability and truck routes.

Conventional delivery is manual and > 50% of operating expenses for the parcel industry

Parcel services already apply a high level of automation, but so far this is limited to sorting. Parcel delivery is also standardized to a significant degree, but human resources continue to play a decisive role. Conventional delivery vehicles are loaded manually and are driven by the delivery personnel to the consignee destinations. The driver carries the parcels to the front door and hands them personally to the consignee. The parcel industry typically reports >50% of operating expenses to this aspect of delivery.

Current drones fail on two tests of delivery: number of drops and parcels per drop

In addition to onerous regulatory obstacles, drone technology also faces significant technical and commercial issues. Commercially we believe current drones fail on two key tests of delivery: the number of drops and the parcels per drop. Current prototypes carry just one package, and after the drone makes its delivery, it has to return to its base to recharge its batteries and pick up the next package. The U.K. Civil Aviation Authority reports that Amazon has been testing drones in the U.K. since 2015 and launched a small-scale drone delivery pilot in the Cambridge area of the U.K. through its "Prime Air" program that made a successful delivery in December 2016.

Drones have been successful in small parcels in certain locations

DHL launched its first Parcelcopter delivery service in 2014. The Parcelcopter was used over a 12 kilometer open water route, delivering parcels to the car-free island of Juist in Lower Saxony. The first generation Parcelcopter could carry up to 1.2kg per trip and provided the community of 1,700 people with basic medical aid. DHL report the third generation Parcelcopter completed a 3-month test period in March 2016 with 130 successful deliveries of sporting goods or medicines up to 2kg to selected private customers at speeds of up to 40mph. In China JD.com began drone deliveries last year. It is currently offering the service in four provinces — Jiangsu, rural Beijing, Sichuan, and Guangxi — and operating 20 fixed routes. By the end of this year, however, the company plans to have 100 routes up and running across China. In the U.S. UPS completed its first drone delivery in late 2016, with the drop of prescription medication to an island off the coast of New England.

DPD estimates that the legal framework for self-driving vehicles for delivery will not be available until 2025 at the earliest

DPD research concluded that self-driving vehicles could make it possible to deliver at least part of a company's parcel volumes with an unprecedented degree of flexibility but cautioned that the legal framework for the application of such delivery concepts will probably not be in place until 2025 at the earliest. Five potential scenarios using autonomous delivery vehicles were identified:

1. Transport by self-drive vehicles to the delivery area
2. Autonomous parking in the city center
3. Autonomous mini transporters in the inner city
4. Mobile pickup stations (using a combination of a driverless delivery van and automated parcel lockers)
5. Consignees controlling the place and time of delivery of a driverless parcel transporter by app.

McKinsey reports that parcel load factors in China can fluctuate from as low as 30% of average during quiet periods, with the peak of Singles Day at 5x–10x when orders can be lost due to delivery delays. McKinsey also reports some 50 companies are testing an Uber-like shipping platform that links shippers with trucks and drivers. The app allows access to a pool of independent urban Chinese drivers with details of delivery records and whether other services are undertaken such as unpacking or installation. The app also offers pricing information, a detailed trip planner, and route maps that help drivers better navigate traffic and improve delivery times plus provides a sequence of suggested pickup sites and optimizes loads for the size of the vehicle. McKinsey reports the app has allowed established players to reduce fleet costs by 30% in some cases and to avoid canceled orders

Warehouses and Global Supply Chains

Global supply chains look set to remain even as manufacturing is increasingly automated, meaning that as many products will still be shipped from overseas, efficiency in storage, and delivery becomes paramount

There are two conflicting trends dictating the size of warehouses. As DHL points out in its report *The 21st Century Spice Trade*, the spectrum of warehouse options goes from one central hub globally to fully localized fulfillment. Both have their challenges — having slow turning SKUs (stock keeping units) sitting in every local fulfillment center is costly, but shipping items that require delivery within hours rather than days is only possible with local fulfillment.

Eurostat estimates the percentage of sellers of online products into the EU that originate from outside of the EU is still a minority, but has risen from 13% in 2012 to 20% in 2016.

DHL estimates that cross-border e-Commerce accounted for 15% of the global e-Commerce market in 2015, and it estimates that this is set to grow at 25% annually through 2020, about twice the rate of domestic e-Commerce, such that cross-border will account for 22% of the total by 2020. *"Having slow-turning SKUs sitting in inventory everywhere — a prerequisite for pure local fulfillment — is much more costly than shipping a certain share of orders cross-border."*

While there has been much debate as to whether the dissipating labor advantage through automated manufacturing and the need for faster delivery might lead to reshoring of manufacturing to the west, the CEO of Adidas said in April 2017 that large-scale reshoring is a "complete illusion" due to entrenched supply chains.

Citi economists highlighted in a January 2017 report the physical goods where China has the largest comparative advantage of production as compared to the U.S. were footwear and apparel & clothing accessories — categories that are also among the most popular for online purchases.

Figure 30. China Has Significant Comparative Advantage versus the U.S. in Manufacturing Products like Footwear, Apparel and Accessories, Due to Embedded and Complex Supply Chains

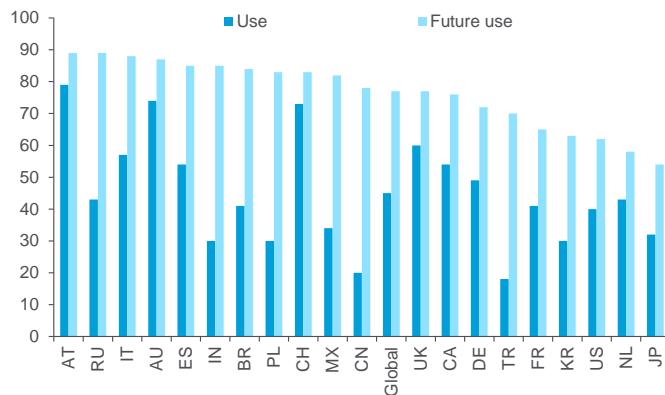
SITC code	Commodity Description	Balassa (1965)	Vollrath (1991)	SITC code	Commodity Description	Balassa (1965)	Vollrath (1991)	SITC code	Commodity Description	Balassa (1965)	Vollrath (1991)
93	Special transactions & commodities not classified	3.63	0.93	58	Plastics in non-primary forms	1.15	0.69	88	Phot. Appar., equip't and optical goods, n.e.s.; watches &	0.68	-0.17
22	Oil-seeds and leguminous fruits (includes soy beans)	2.99	3.21	71	Power-generating machinery and equipment	1.15	-0.06	2	Dairy products and birds' eggs	0.64	1.07
25	Pulp and waste paper	2.20	1.51	51	Organic chemicals	1.14	-0.21	11	Beverages	0.62	-0.92
21	Hides, skins and furskins, raw	2.12	2.69	66	Non-metallic mineral manufactures, n.e.s.	1.11	-0.07	68	Non-ferrous metals	0.60	-0.27
26	Textile fibres (ex-wool tops) & wastes	1.89	1.80	54	Medicinal and pharmaceutical products	1.04	-0.08	12	Tobacco and tobacco manufactures	0.57	0.41
8	Feeding stuff for animals (not including unmilled cereals)	1.78	1.80	23	Crude rubber (including synthetic and reclaimed)	1.03	0.48	61	Leather, leather manufactures n.e.s., and dressed furskins	0.53	0.43
96	Coin (other than gold coin), not being legal tender	1.63	1.62	64	Paper, paperboard & art. of paper pulp, paper or paperboard	1.02	0.30	79	Other transport equipment	0.53	-0.50
59	Chemical materials and products, n.e.s.	1.62	1.05	78	Road vehicles (including air-cushion vehicles)	0.99	-0.43	6	Sugars, sugar preparations and honey	0.51	-0.55
87	Profess., scientific & controlling instrum. & appar., n.e.s.	1.61	0.52	75	Office machines and automatic data-processing machines	0.94	-0.48	82	Furniture and parts thereof: bedding, mattresses, mattress	0.50	-1.45
4	Cereals and cereal preparations	1.51	1.22	28	Metaliferous ores and metal scrap	0.92	1.64	65	Textile yarn, fabrics, made-up articles, n.e.s., and related p	0.50	-0.55
52	Inorganic chemicals	1.40	0.50	32	Coal, coke and briquettes	0.92	2.38	3	Fish (not marine mammals), crustaceans, molluscs and a	0.50	-0.82
41	Animal oils and fats	1.35	1.16	62	Rubber manufactures, n.e.s.	0.89	-0.30	34	Gas, natural and manufactured	0.48	0.66
57	Plastics in primary forms	1.34	1.27	73	Metalworking machinery	0.86	-0.04	67	Iron and steel	0.45	-0.48
72	Machinery specialized for particular industries	1.34	0.42	27	Crude fertilizers & minerals (ex-coal, petrol & precious stones)	0.85	0.42	81	Prefabricated buildings: sanitary, plumbing, heating and light	0.44	-1.19
1	Meat and meat preparations	1.25	0.78	69	Manufactures of metals, n.e.s.	0.82	-0.22	63	Cork and wood manufactures (excluding furniture)	0.40	-1.13
9	Miscellaneous edible products and preparations	1.24	1.03	77	Electrical mach., apparatus & appliances, n.e.s., & parts	0.82	0.09	7	Coffee, tea, cocoa, spices, and manufactures thereof	0.40	-0.90
24	Cork and wood	1.23	0.51	29	Crude animal and vegetable materials, n.e.s.	0.81	-0.14	40	Live animals other than animals of division 03	0.40	-1.10
74	Gen. industr mach. & equip't, n.e.s., & mach.parts, n.e.s.	1.22	0.15	56	Fertilizers (other than those of group 27)	0.79	-0.10	42	Fixed vegetable fats and oils, crude, refined or fractionated	0.38	-0.37
89	Miscellaneous manufactured articles, n.e.s.	1.20	-0.16	33	Petroleum, petroleum products and related materials	0.79	-0.17	83	Travel goods, handbags and similar containers	0.21	-1.94
55	Ess. Oils & perfume materials; toilet, cleansing prep.	1.17	0.53	97	Gold, non-monetary (excluding gold ores and concentrates)	0.78	0.84	84	Articles of apparel and clothing accessories	0.15	-2.40
53	Dyeing, tanning and colouring materials	1.17	1.04	76	Telecommunications and sound-recording and reproducing	0.71	-0.65	85	Footwear	0.12	-2.60
5	Vegetables and fruit	1.16	0.17	43	Animal or vegetable fats & oils, processed: waxes, n.e.s.	0.69	1.03	35	Electric current	0.09	-1.91

Source: UN Comtrade, Citi Macro Research; table shows relative Comparative Advantage across 66 Product Categories (by 2-Digit SITC Rev 4 codes)

The main reasons for shopping abroad are that products are not available domestically (73%) and that prices are lower elsewhere (63%)

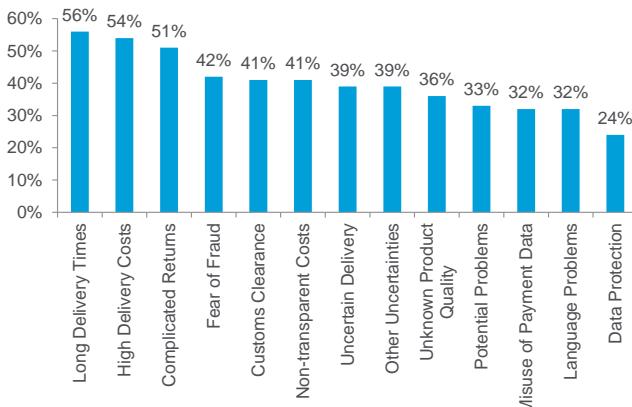
DHL published [Shop the World: Consumer attitudes towards global distance selling](#) in June 2014 that examined in-depth attitudes to distance shopping selling across 20 countries. The DHL survey identified significant opportunity for increased cross-border e-Commerce in most countries (Figure 31). The main reasons for shopping abroad are that products are not available domestically (73%) and that prices are lower elsewhere (63%). In emerging economies, better quality and protection against counterfeit goods and product piracy were key factors. These were cited particularly frequently by customers in China, India, and Russia. The 20% of all Internet users that would not order from overseas in the future include experienced distance-selling consumers who think the obstacles and problems of ordering abroad are just too big. The biggest obstacles (Figure 32) are seen in the delivery process: Long delivery times (56%), high delivery charges (54%), and complex return management (51%). These were cited to equal extent by respondents in all countries.

Figure 31. Use and Future Use of Cross-Border e-Commerce (%)



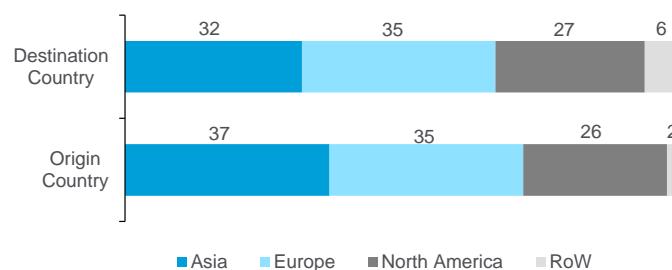
Source: DHL

Figure 32. Barriers to Ordering Abroad



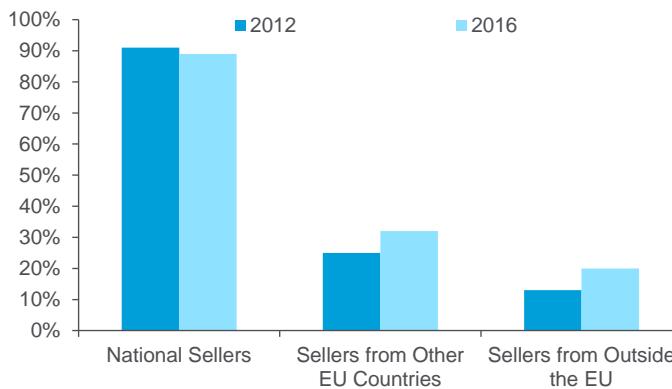
Source: DHL

Figure 33. Share of High Basket Value Transactions by Region (Figures in %, 100% = ~\$30bn)



Source: DHL

Figure 34. National and Cross-Border Purchases by e-Shoppers



Source: Eurostat, Citi Research

Figure 35. Inventory-to-Sales Ratios Have Trended Higher After a 20-Year Secular Decline

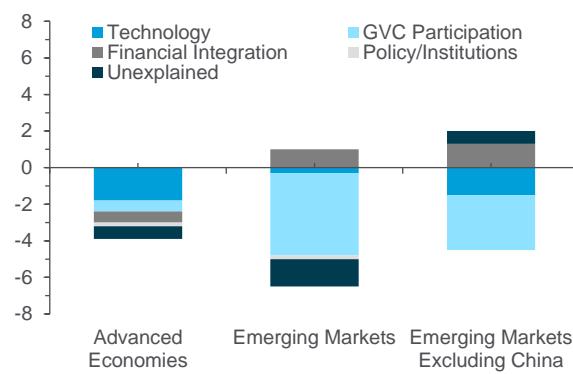


Source: U.S. Census Bureau, Citi Research

The Impact on Labor

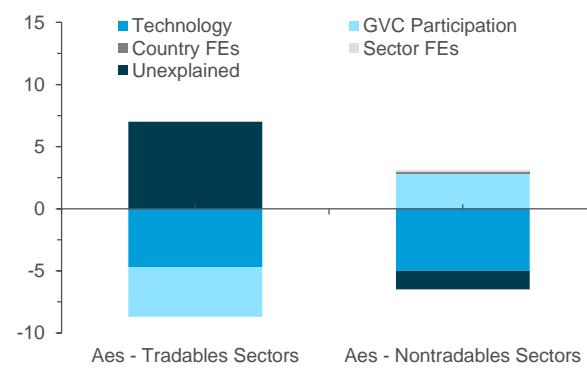
In its World Economic Outlook from April 2017, the IMF explored the downward trends in the labor share of income since the early 1990s. As with other studies, attention has focused on two areas: technology and globalization. The study notes that while the distinct labor impacts of global integration and technology “are both conceptually and empirically difficult to disentangle,” the IMF nonetheless concludes that, for advanced economies, technology is the largest contributor to the change in labor shares in the large majority of countries.

Figure 36. Contributions to Aggregate Labor Share Changes (1993–2014)



Source: IMF

Figure 37. Contributions to Aggregate Labor Share Changes (1993–2014)



Source: IMF

Labor in Retailing and Storage Are at High Risk of Automation

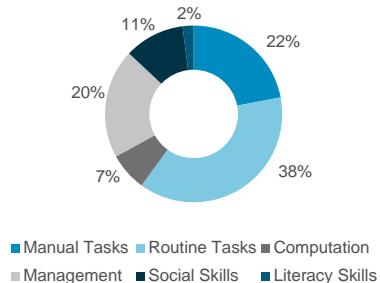
In this report, we focus on automation with respect to e-Commerce, including the impact on retailers, warehousing, and delivery. A PwC report from March 2017 found that in the U.K., the sector with the highest risk of automation to jobs was Transportation & Storage, with 56% of jobs at potential high risk of automation by 2030. The ONS classification of Transportation & Storage includes Warehousing & Support Activities as well as Postal & Courier Activities (in addition to transportation activities.) According to the report, jobs in Wholesale & Retail Trade have an above-average risk, of 44% risk from automation; as the sector with the highest employment share in the U.K., it accounts for the highest number of jobs at high risk of automation.

Figure 38. Employment Shares, Estimated Proportion, and Total Number of Employees at Potential High Risk of Automation for all U.K. Industry Sectors

Industry	Employment Share (%)	Job Automation (% at Potential High Risk)	Jobs at High Risk of Automation (Millions)
Wholesale and retail trade	14.80%	44.00%	2.25
Manufacturing	7.60%	46.40%	1.22
Administrative and support services	8.40%	37.40%	1.09
Transportation and storage	4.90%	56.40%	0.95
Professional, scientific and technical	8.80%	25.60%	0.78
Human health and social work	12.40%	17.00%	0.73
Accommodation and food service	6.70%	25.50%	0.59
Construction	6.40%	23.70%	0.52
Public administration and defense	4.30%	32.10%	0.47
Information and communication	4.10%	27.30%	0.39
Financial and insurance	3.20%	32.20%	0.35
Education	8.70%	8.50%	0.26
Arts and entertainment	2.90%	22.30%	0.22
Other services	2.70%	18.60%	0.17
Real estate	1.70%	28.20%	0.16
Water, sewage and waste management	0.60%	62.60%	0.13
Agriculture, forestry and fishing	1.10%	18.70%	0.07
Electricity and gas supply	0.40%	31.80%	0.05
Mining and quarrying	0.20%	23.10%	0.01
Domestic personnel and self-subsistence	0.30%	8.10%	0.01
Total for all sectors	100%	30%	10.4

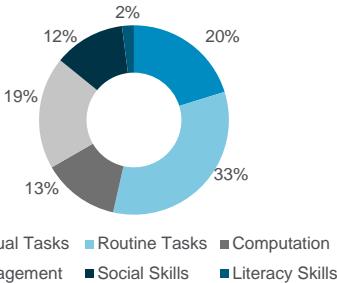
Source: ONS for Employment Shares (2016), PwC

Figure 39. Task Composition in the U.K. for Transportation & Storage



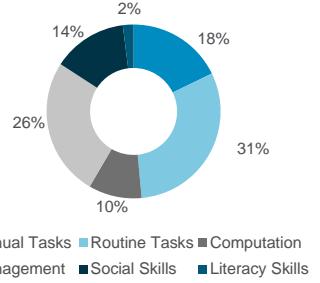
Source: PwC

Figure 40. Task Composition in the U.K. for Manufacturing



Source: PwC

Figure 41. Task Composition in the U.K. for Wholesale and Retail Trade



Source: PwC

Labor was cited as the key risk to e-Commerce-related growth for warehouse brokers and property owners

Automated picking in unstructured environments still remains a difficult challenge

Labor availability is cited as one of the top three issues for warehouses over the next three years

The Biggest Impact Is Yet to Come

While automation clearly presents a risk to jobs in the medium term in warehousing and storage, it seems that it is not yet the case. As part of a recent research report, Citi's U.S. real estate research team found that labor was cited as the key risk that could slow down e-Commerce-related growth for warehouse brokers and property owners, noting that *"it appears given the nation is in full-employment, that we are in a labor shortage for warehouse and construction jobs."* They add that robotics may be more likely to be put to use in more rural locations initially to mitigate hiring difficulties in these areas, but that employers have to offer incentives such as tuition reimbursement, transportation to work, and better on-site amenities in order to attract workers. In terms of scale, an Amazon facility can employ ~2,500 people, jumping to ~5,000 during peak season.

So why is warehousing still such a large user of labor? For some parts, the hand-eye coordination, dexterity, and flexibility of the human cannot yet be replaced. Amazon still runs its Amazon Robotics Challenge (formerly the Amazon Picking Challenge) in order to bring together academic and industrial know-how to improve warehouse picking technologies. Amazon notes that while it has been successful at removing much of the walking and searching for items within a warehouse, *"commercially viable automated picking in unstructured environments still remains a difficult challenge."*

It's not just technology; cost matters too. Amazon said in 2016 that some fulfillment centers are "fully outfitted" in robots while others aren't "for economic reasons".

A 2016 survey for Modern Materials Handling, a trade magazine for the warehouse and logistics industry, found that labor availability was one of the top three issues set to become more important for warehouses over the next three years.

This might suggest that, at least for warehouse automation, the challenges for labor are largely ahead, not behind us.

Serving the Consumer

Pull from the consumer is ultimately the driver of e-Commerce growth

Ultimately, the driver of e-Commerce growth will always be the "pull" from the consumer. In this chapter we look at the online penetration of retail by category and geography to understand why there are different levels of development and then look at what has driven the growth of e-Commerce.

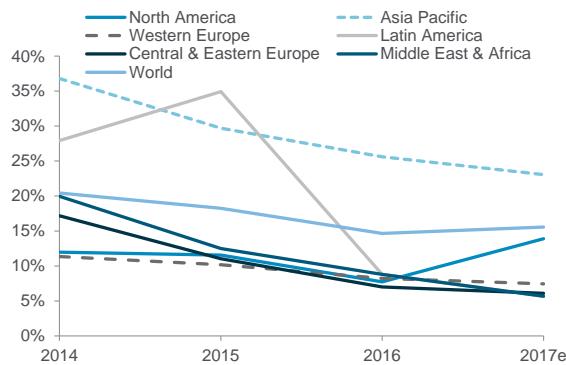
Later, we look at the implications for the retail sector, how retailers are adapting to cope with e-Commerce and ultimately what impact further automation may have on the retail landscape.

e-Commerce Growth

Global e-Commerce sales have grown at a compound annual growth rate (CAGR) of 20% over the last decade, according to Euromonitor International. In this time, the amount of retail sales transacted online has gone from ~2% of the total retail sales to ~8%.

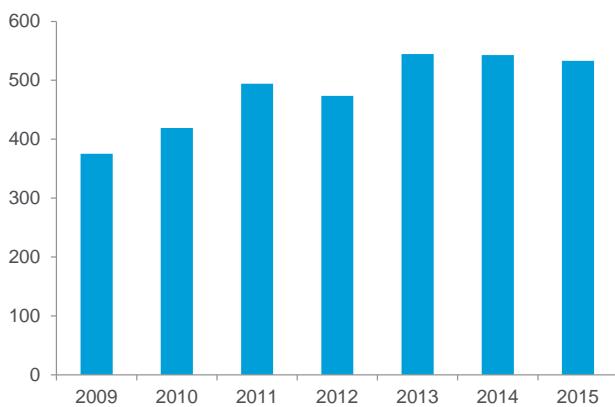
This growth is likely to continue.....

Figure 42. Global e-Commerce Growth by Region 2014-17 (% , YoY)



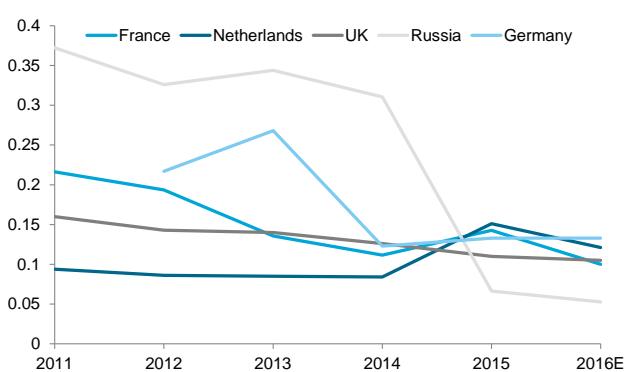
Source: eMarketer

Figure 44. U.K. e-Commerce Sales, 2008-2015 (in GBP Billion)



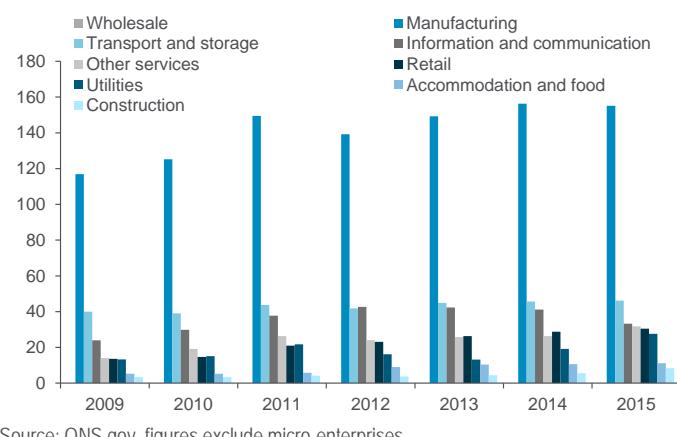
Source: ONS.gov, figures exclude micro-enterprises

Figure 43. Europe e-Commerce Growth by Country (% , YoY)



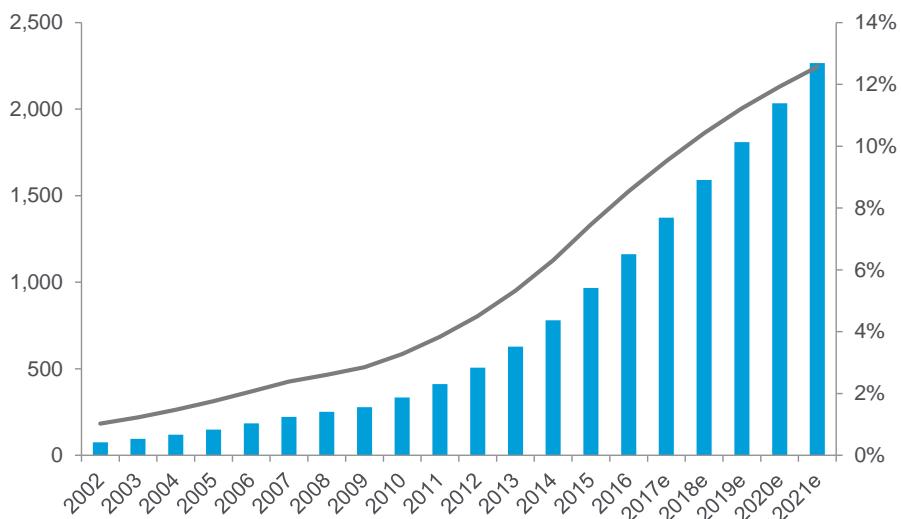
Source: E-Commerce Europe

Figure 45. U.K. e-Commerce Sales by Industry (in GBP Billion)



Source: ONS.gov, figures exclude micro-enterprises

Figure 46. e-Commerce Size (in US\$bn, LHS) and % of Overall Retail (RHS) – Global



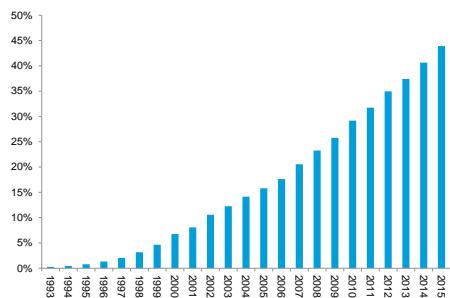
Source: Euromonitor International

Drivers of e-Commerce

There are a number of factors that have driven consumers to use online retail, including technology, improved payment methods, mobile access, and delivery methods.

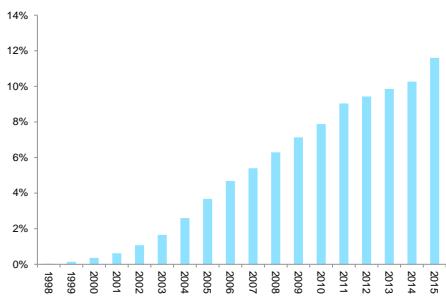
Internet access and broadband access have increased dramatically since inception in 1989. Globally, Internet users have increased from 7% of the population in 2000 to over 44% by 2015. Looking at more developed nations such as the U.S., Japan, the U.K., France, and Germany, in the early 1990s less than 5% of the populace used the Internet; currently well over 80% do.

Figure 47. Global Internet Users (% of Population)



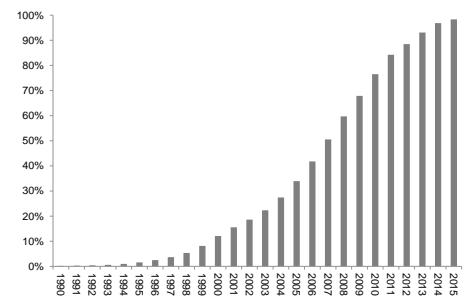
Source: World Bank Data, Citi Research

Figure 48. Global Broadband Subscribers (% of Population)



Source: World Bank Data, Citi Research

Figure 49. Global Mobile Phone Subscribers (% of Population)

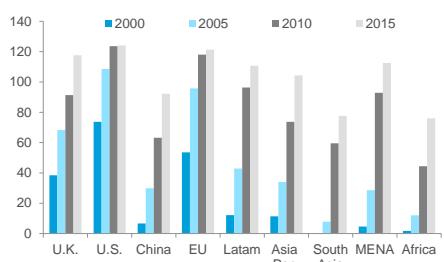


Source: World Bank Data, Citi Research

Mobile Data Evolution

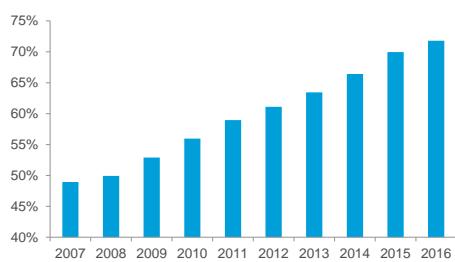
The advent of mobile Internet and increasing ability and willingness of consumers to browse and purchase goods over mobile devices through specialized websites and apps are opening up a new channel of online growth that is likely to drive majority of online growth in the future.

Figure 50. Mobile Phone Penetration by Region



Source: World Bank Data, Citi Research

Figure 51. Mobile as % of Online Retail Sales — Global



Source: Euromonitor International, Citi Research

Figure 52. Mobile as % of Online Retail Sales Global

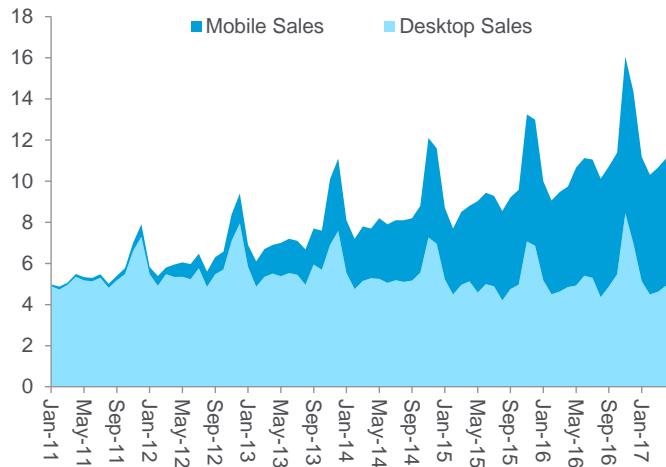


Source: Euromonitor International, Citi Research

Mobile phone penetration is above 75% in every major region. As affordable smartphones proliferate and mobile data services and access such as Wi-Fi networks increase, this will allow consumers that may not have access to fixed-line Internet infrastructure to access the Internet and online shopping channels.

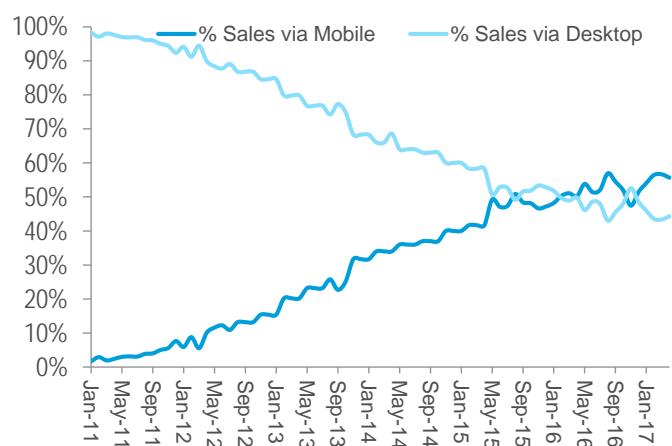
Mobile data also allows consumers to spend a much larger amount of time browsing and shopping online, often in locations and at times when shopping (fixed online or traditional) would not otherwise be possible. The mix of mobile shopping as a proportion of online shopping has increased rapidly in recent years and now represents almost 20% of all online purchases. In the U.K. it is now over 50% of online purchases, from less than 5% in 2011.

Figure 53. K.: Online Retail Split by Desktop and Mobile (£bn)



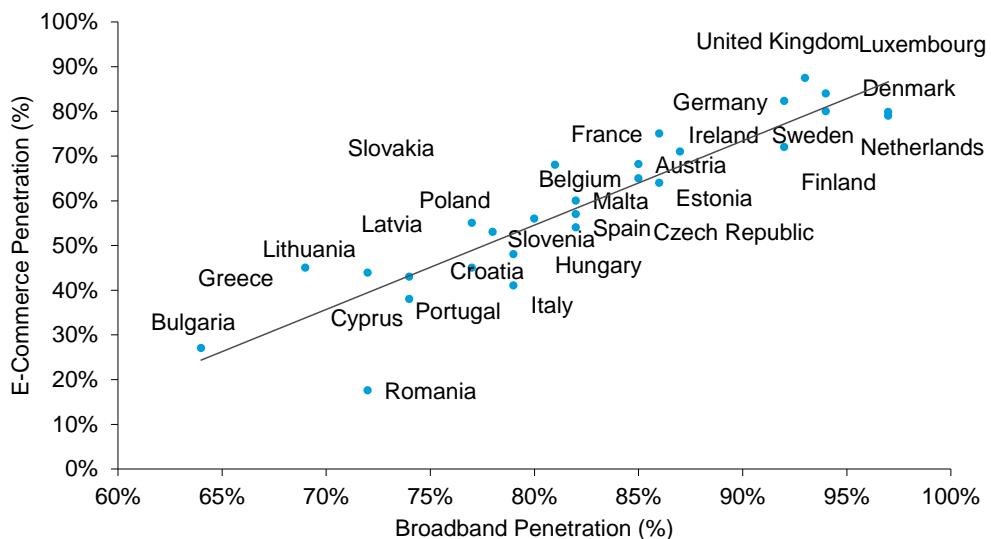
Source: IMRG, Citi Research

Figure 54. U.K.: Online Retail Split by Desktop and Mobile



Source: IMRG, Citi Research

Figure 55. Broadband Penetration Is a Key Enabler of e-Commerce

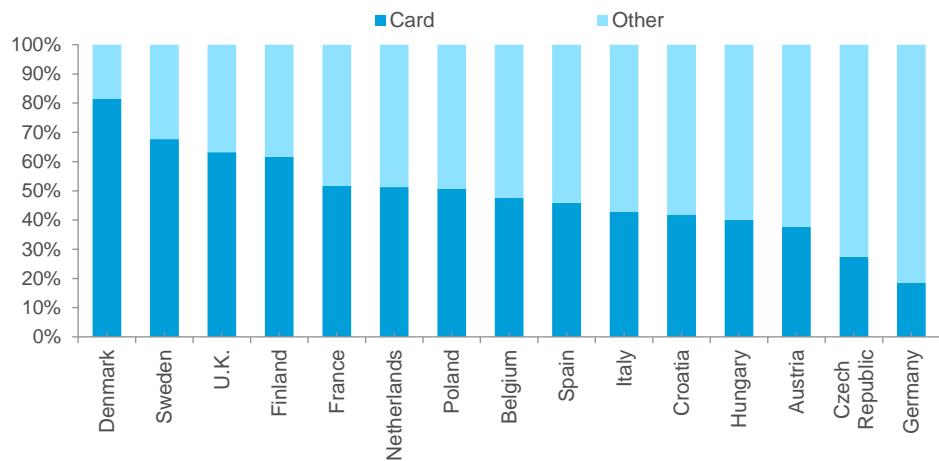


Source: Citi Research, Eurostat

Correct Payment Method

As the chart below shows, the main payment methods differ hugely across Europe and therefore one of the main challenges facing online retail companies on the continent has been in developing ways for customers to transact online.

Figure 56. Share of Card vs ACH Transactions Across European Countries



Note: Other payments in the above statistics include credit transfers, direct debits, payroll, e-money and vendor payments

Source: European Central Bank, Citi Research

Factors affecting choice of payment method include:

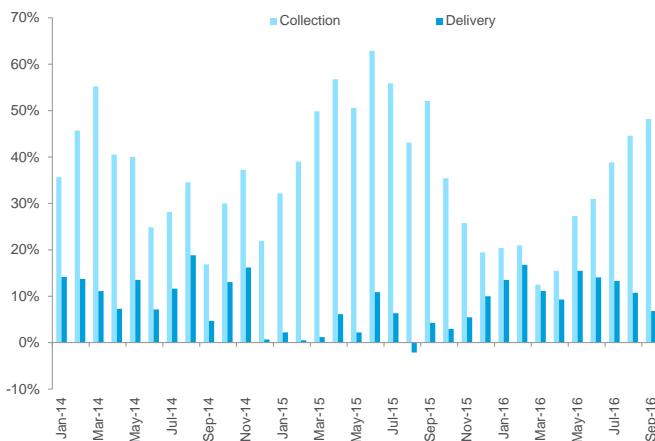
1. **Local facilities and products:** These are perceived as more secure than international payment methods. Given that fraud is a significant concern for consumers, many of them opt for a local payment path. Also, local services tend to be cheaper than international ones.
2. **Security and risks:** Again, fraud is the main concern.

3. **Easiness and rapidity:** The main aim of e-Commerce is to reduce time consumption and transaction costs, so payment methods as well must provide a quick and easy check-out.
4. **Business type:** The nature of the payment method depends on the type of goods bought.
5. **Average basket value:** Larger amounts are more likely to be paid by bank transfer or invoice while cart values near the average are usually paid for using bank cards.

Convenient Delivery Proposition

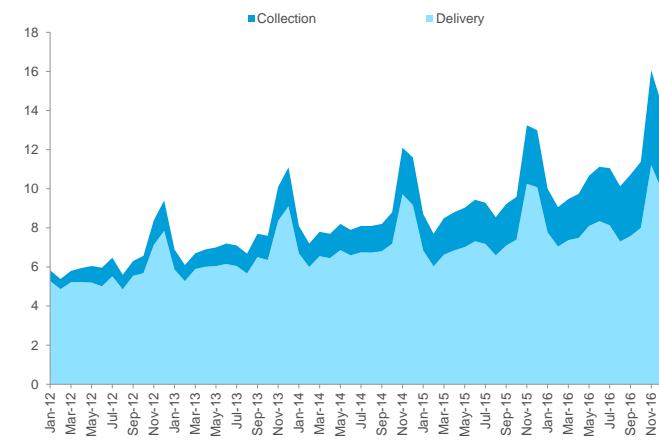
One of the major areas of growth in online retail is the use of alternative delivery mechanisms, particularly the use of "Click and Collect" whereby consumers can order the goods online for pick-up at the retailers store, or at another location such as another retailers' store, a collection locker, or using schemes such as Collect+ or Doddle.

Figure 57. U.K.: Annual Growth of Collection and Delivery



Source: IMRG, Citi Research

Figure 58. U.K.: Split of Online Retail Sales by Fulfillment Method



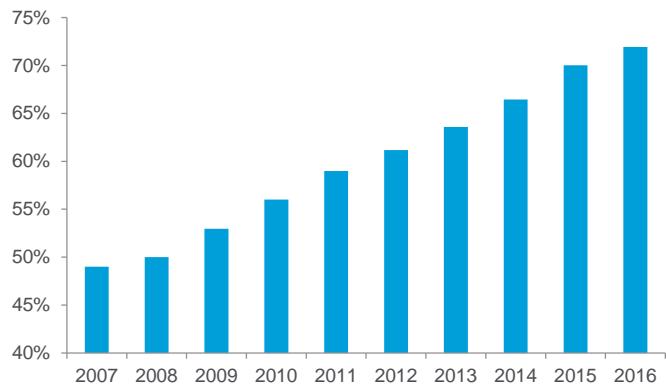
Source: IMRG, Citi Research

In the U.K., delivery has grown at 10% per year over the last three years, but alternative fulfillment has grown at almost 40% per year and now accounts for almost 30% of online sales versus 15% four years ago.

Pure Play Online Retail Outpacing Multichannel

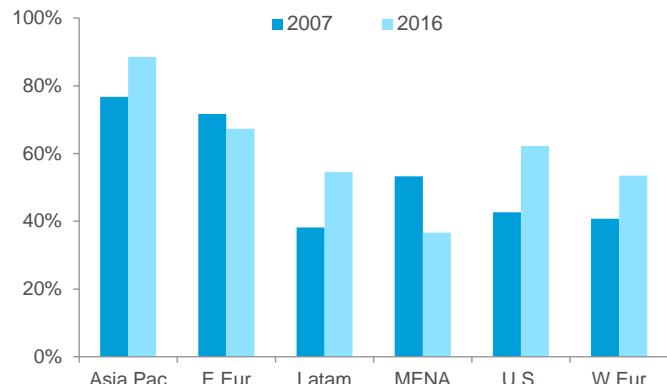
Due to the cannibalistic effects of growing an online channel and an owner's proclivity to protect near-term margins (see below), the majority of innovation and development in the online retail space is spearheaded by pure-play online retailers. This is helped by the fact that owners of these companies are usually willing to sacrifice margins and free cash flow for growth. This effect is exerting ever more pressure on traditional brick-and-mortar retailers, which are being forced to close space.

Figure 59. Pure-Play Online as % of Internet Retail: Global



Source: Euromonitor International, Citi Research

Figure 60. Pure-Play Online as % of Internet Retail: Selected Regions



Source: Euromonitor International, Citi Research

How Does Automation Help Online Retail?

Automation is a very important factor in driving the growth of online retail as it can drive large ranges and faster throughput.

Product Assortment

A massive advantage of online operations for retailers is that a very large stock file can be held in one location and distributed globally. This allows retailers to stock many more products (SKUs) than are available in each individual store without the same associated inventory risk.

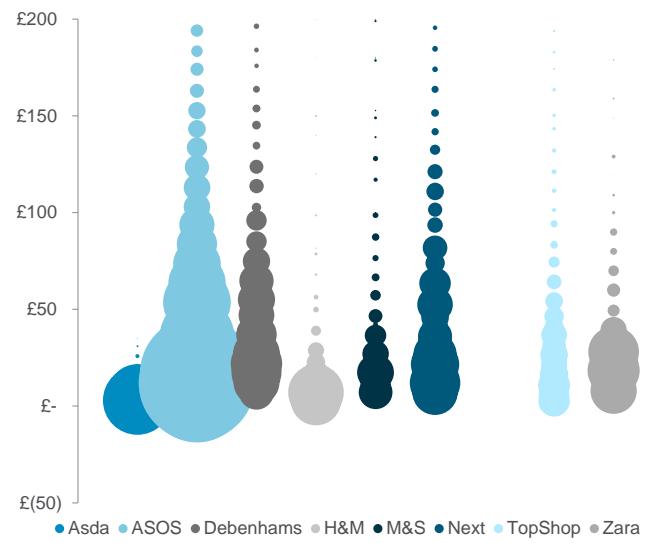
The success of aggregation websites shows clearly that a larger choice of products drives sales growth over time.

Figure 61. Online Aggregation Model



Source: Citi Research

Figure 62. Illustration of Product Range by Retailer: U.K. Clothing



Source: Citi Research

Automation of warehouses allows retailer to handle ever larger volumes and ranges of stock, which in turn drives growth.

Faster Throughput

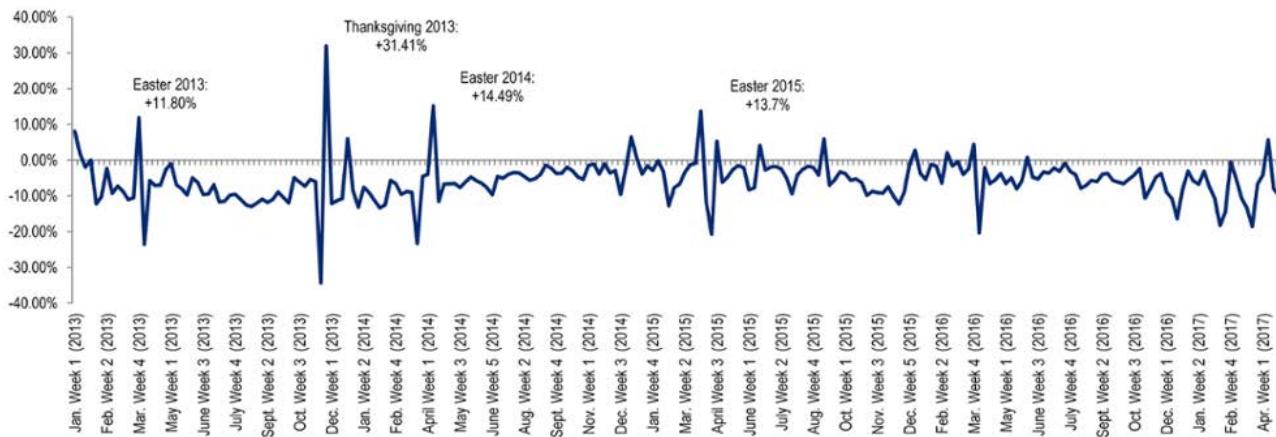
In more developed online markets, there is a clear move for retailers to offer later cut-offs for online delivery with peak online shopping hours in the U.K. now said to be 8–10 p.m. Retailers are increasingly offering some kind of next-day delivery with a 10 p.m. or even midnight cut-off.

Automation massively reduces the time needed for a distribution center to process an order, thereby enabling them to more readily offer shorter delivery times.

Growth of Online Retail Not Positive for Overall Retail Industry

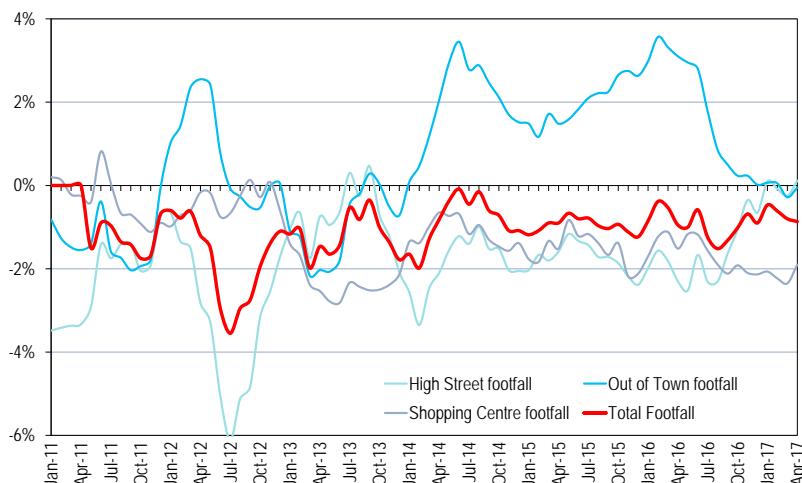
Over the last few years, it has become increasingly clear that the growth of online retail is coming at the expense of traditional retail models. Traditional brick-and-mortar retailers continue investing heavily in omni-channel capabilities to maintain share in their local markets and gain access to new consumers. As online has grown, physical mall footfall has continued to weaken.

Figure 63. Shoppertrak Traffic: Physical Mall Footfall Continues to Weaken as Consumers Increasingly Shop Online...



Source: Shoppertrak, Citi U.S. Consumer Research

Figure 64. U.K. Footfall Has Been in Constant Decline Since Early 2011

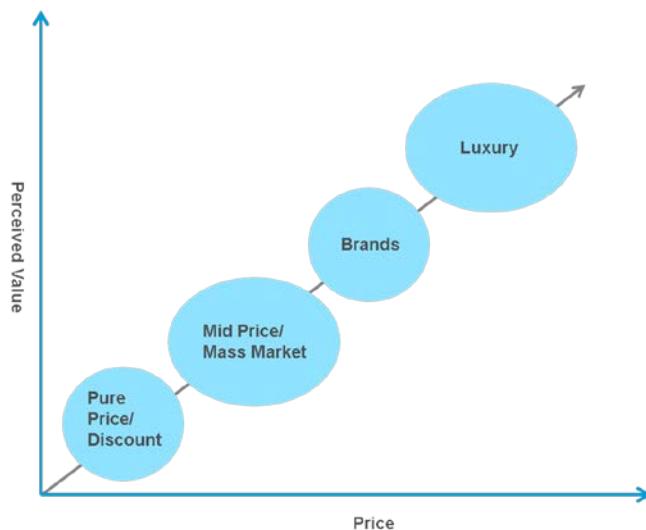


Source: BRC, Citi Research

We believe the successful retailers of tomorrow will need to keep pace with shifting consumer behavior that tends to demand high levels of service, speed, unique experiences, and differentiated product.

As well as the type of products sold, the positioning of the retailer is also important when determining how online will affect the business model.

Figure 65. Citi's Global Consumer Discretionary Positioning Framework



Source: Citi Research

Using Citi's Global Consumer Discretionary Positioning Framework we show that online works best in the mass market at scale.

1. **Pure price/discount:** Due to low average basket sizes and low gross margins, the economics of selling discount goods online is very difficult to make feasible. We therefore expect that discount retail remains a predominantly offline activity.
2. **Luxury:** Luxury is a sector where the strength of the brands remains paramount and sales volumes are comparatively low. In order to protect brand strength, luxury brands will be highly selective on the distribution channels used, and we do not expect a large migration to aggregation websites.
3. **Mid-price/mass market:** In this segment, the price and average basket size makes online a viable option economically. It is also an area of the market where scale is important. It is these areas where online is likely to be the dominant growth channel.

The migration of sales to online channels is creating a dynamic in which retailers have to cover the costs of online logistics while store-based costs remain. Whether retailers are getting a sales uplift from online or simply experiencing a shift in channel is relevant, but profitability is affected in both cases.

Below we attempt to illustrate these dynamics for a generic store-based retailer; while these examples are not company-specific we believe they provide a good basis on which to think about online sales.

1. Sales Migrate to Online Channel

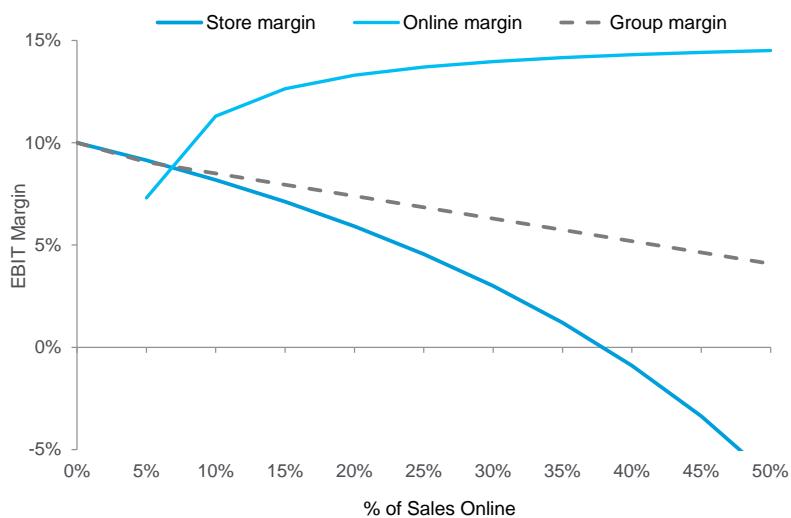
In this case, an established store-based retailer experiences a channel shift so that sales that were previously in store are purchased online without any uplift to total volumes.

All fixed costs at the store remain in place, while some of the variable costs can be lowered due to the lower sales volumes.

The dynamics of the store-based profitability would be that the deleverage of the fixed costs sees margins under intense pressure and trending to zero and below as sales migrate online. Even though the online margin is higher than the store average, this deleverage causes the total group earnings before interest and tax (EBIT) margins to decline.

Retailers that have fixed store costs would typically prefer the marginal customer to go to a store rather than online (where there variable costs associated with every purchase). To preserve the group EBIT margin, the retailer could close space and therefore reduce fixed store costs.

Figure 66. Example Retailer: Sales Migrate to Online

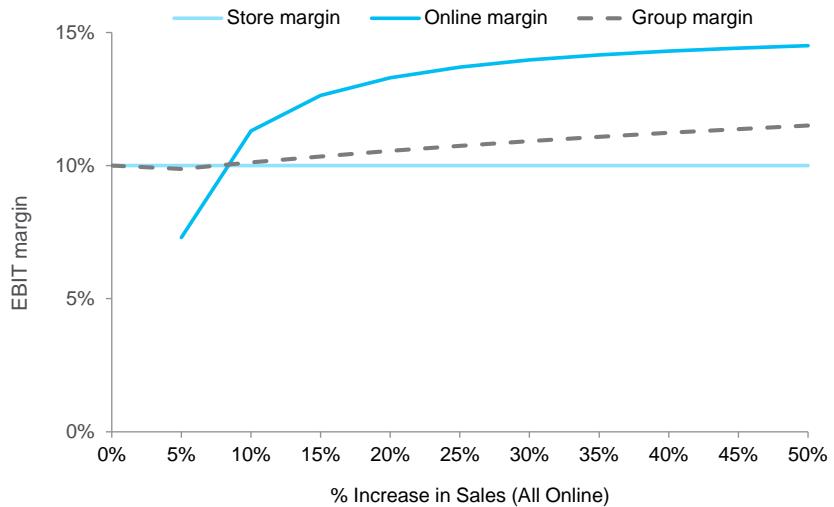


Source: Citi Research

2. Online Generates an Extra Sales Channel

In this case, an established store-based retailer opens an online channel that generates extra sales for the group without any cannibalization of the existing sales base. This is the best scenario for any retailer and could, after online sales have reached a critical mass, generate margin enhancements across the group, providing online margin is higher than the store margin. However, for some retailers, especially those with lower average ticket sizes, high return rates, and paid for shipping, it may be difficult for online sales to match the store margin.

Figure 67. Example Retailer: Extra Sales are Generated Online



Source: Citi Research

3. Online Generates an Extra Sales Channel, Some Sales Migrate

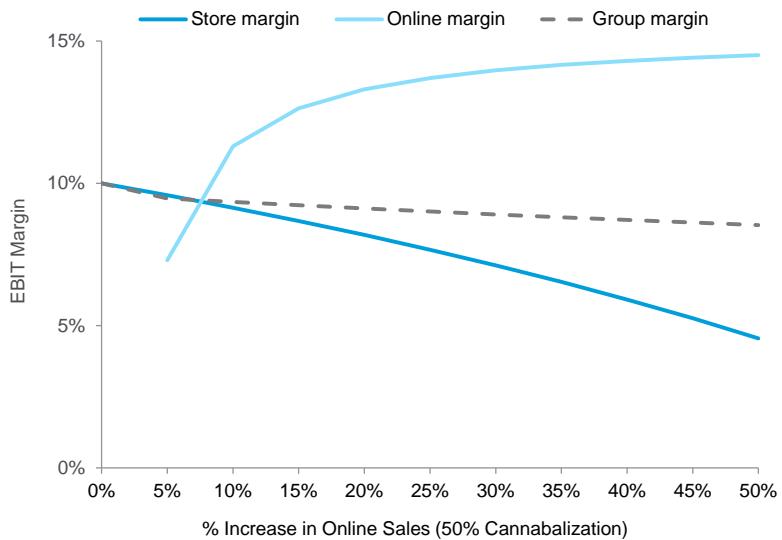
In this scenario, the retailer experiences a mixed effect from online. While the online channel does generate new sales, it also cannibalizes some of the existing sales base (in this example, each online sales increase is considered to be half new and half from pre-existing store sales).

We consider this to be the most common example, although the level of online sales and cannibalization will differ by retailer (as will almost every aspect of the profit and loss (P&L)).

It can be seen in this example that even with a highly profitable online channel, the deleverage of the fixed cost of the stores creates a dynamic where the retailer will find it very difficult to hold group EBIT margins.

Using this example with a different ratio suggests that if only 25% of the online sales that a retailer generates are cannibalizing the store sales, the group margin will be flat.

Figure 68. Example Retailer: Online Generates Extra Sales, 50% of Which Migrate from In-Store



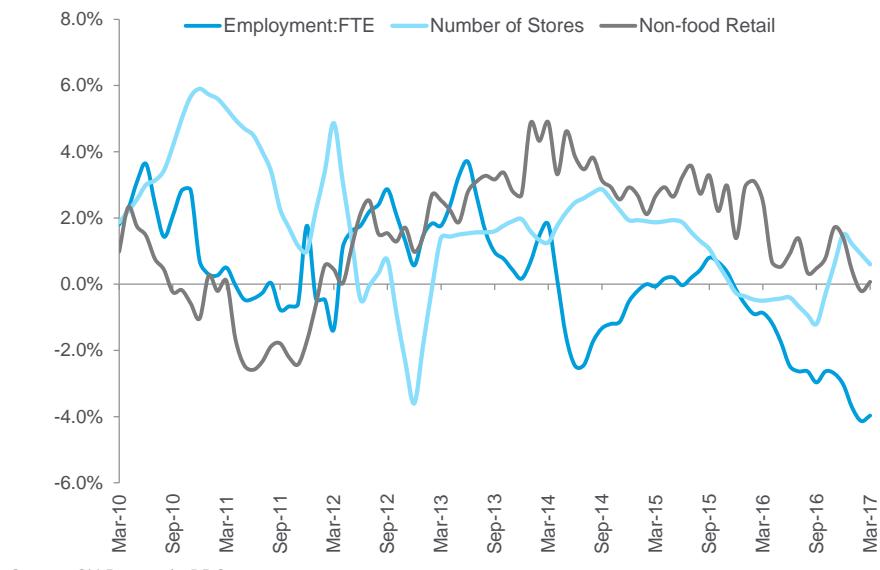
Source: Citi Research

Negative Implications for Employment

As the cost of technology falls, the willingness of retailers to use automation to reduce costs and possibly increase the quality of service increases. This dynamic is only exacerbated in markets where costs of labor are increasing.

The impact on retail employment can clearly be seen in the U.K. where retail employment has declined 3.5% faster than non-food retail sales since the start of 2014.

Figure 69. U.K. Retail Employment Growth Relative to Store Growth & Non-Food Retail Growth



Source: Citi Research, BRC

Warehouse Automation

90% of the final “picks” from the warehouse shelf are still done by hand

Warehouses are experiencing a secular increase in investment, driven by automation and the integration of supply chains to better serve e-Commerce.

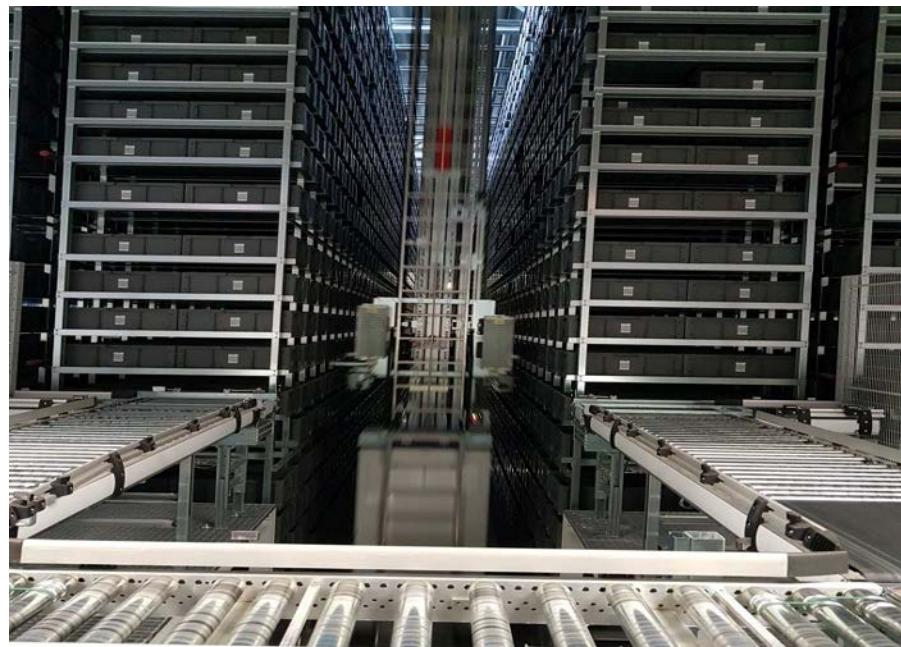
DHL reports that, according to a 2016 study by supply chain consultancy St. Onge, 80% of warehouses are still manually operated. Schaeffer, a supplier of automation, estimates that 90% of the final “picks” from the warehouse shelf are still done by hand, partly for cost reasons and partly for technology reasons. Mechanized warehouses (for example using conveyors and other mechanical material handling equipment, but not necessarily “automated”) are more common, but mechanized warehouses still only account for 15% of total warehouses, according to the DHL report.

What is Warehouse Automation?

Warehouse automation can be a catch-all term ranging from storage and retrieval systems, picking systems, sortation systems, conveyors, and palletizing systems. Warehouses mechanisms also include conveyor systems and warehouse trucks.

- **Picking systems are still largely manual:** Picking can be quite manual, especially where customer orders are for a wide variety of SKUs (for example online grocery shopping). Picking is usually the most labor intense part of the fulfillment center, as automating becomes increasingly challenging as the number of SKUs goes up. Barcode scanning can minimize errors but RFID (radio frequency) is quicker for product identification. Even if pickers still pick individual items, automated storage and retrieval systems can bring the goods to the picker, and order picking robots can improve this further still. Technologies like pick-to-light or pick-to-voice can also increase the efficiency of the human worker even if the task is not truly automated.
- **Automated sorting already widely adopted:** Used to sort cartons coming off the production line or packages out of the warehouse conveyor system before shipping. Sortation systems are already widely adopted for small packages and parcels (see Figure 74).
- **Palletizing systems – Robots widely adopted but further improvements can be made:** Most goods enter the warehouse (and may also leave) on standard pallets. Palletizing systems automatically load pallets. Robots used for palletizing are not a new concept, although smarter systems to consider product weight, size, and crushability can now be used. Connecting palletizing systems to other parts of the warehouse is also an opportunity.
- **Automated storage and retrieval systems (AS/RS) are among the most complex parts of fulfillment:** AS/RS systems are arguably the most complex part of automating a warehouse, and they are essentially the automated storage of crates and pallets after delivery from supplier and the retrieval to allow a picker to select the appropriate product. It also includes automated racking, shelving, and shuttle systems and allows for far denser warehouses. MIAS, a provider of stackers recently bought by Jungheinrich, has automated stackers that can travel at up to 5 meters per second and reach 43 meters high. Autonomous guided vehicles (AGVs) are a subcategory of automated storage and retrieval systems.

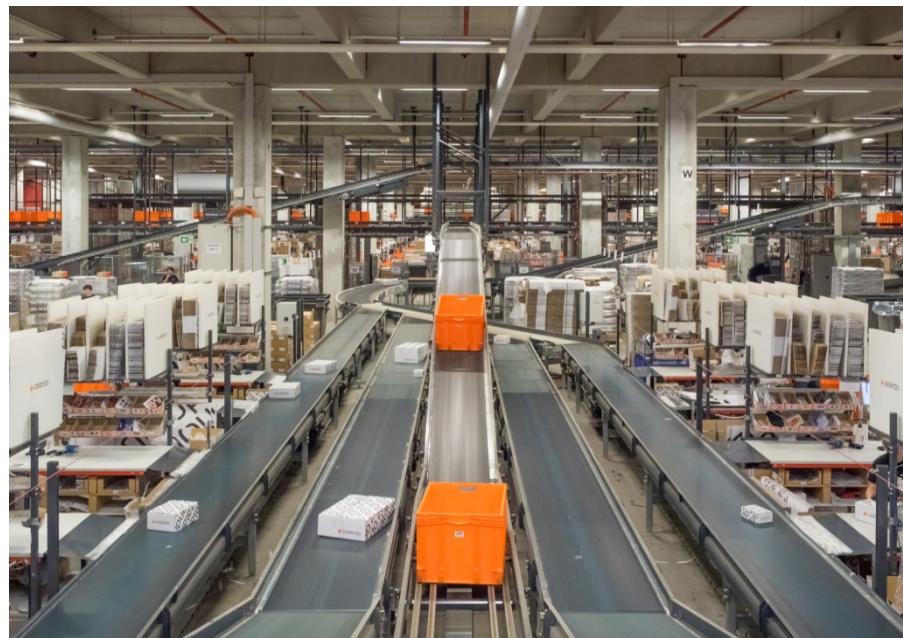
Figure 70. A Glimpse of Jungheinrich's Giant Stackers



Source: Jungheinrich

- **Warehouse management systems (WMS):** WMS software supports and integrates all of the above. Some of the major supply chain management software suppliers are noted in Figure 75).
- **Grid systems:** Grid and bin warehouses have fundamentally changed the nature of warehouse design, with AGV robots running on a grid system to load and unload from bins below. Examples include Swisslog's AutoStore and Ocado's Smart Platform.

Figure 71. A Look Inside the Zalando Warehouse



Source: Zalando

Figure 72. Zalando Warehouse



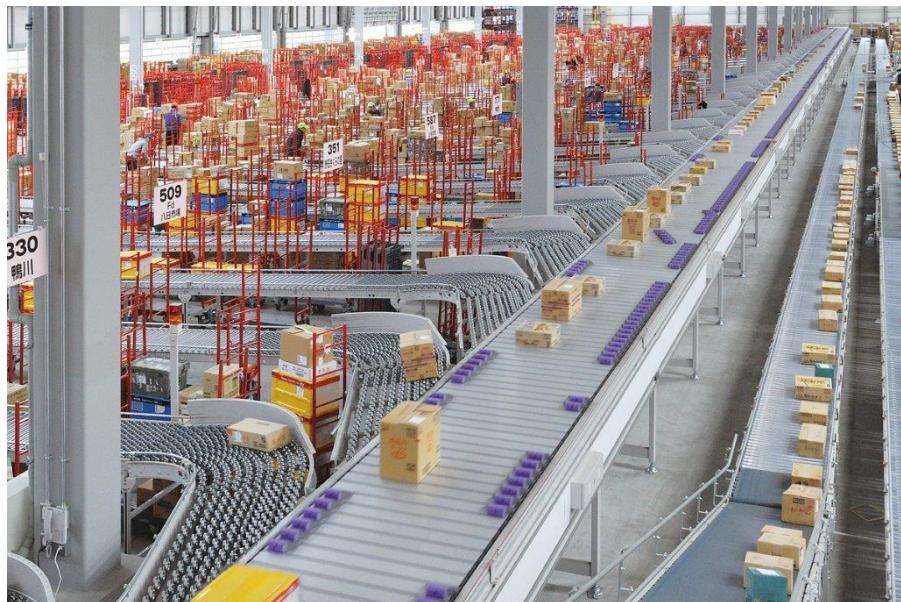
Source: Zalando

Figure 73. Zalando Warehouse



Source: Zalando

Figure 74. Automated Sorting Systems are Already Widely Adopted



Source: Daifuku

Figure 75. Top 20 Supply Chain Management Software Suppliers

	Revenue (US\$m, 2014)	SCP	WMS	MES/MRP	TMS
SAP	2,563	✓	✓	✓	✓
Oracle	1,451	✓	✓	✓	✓
JDA Software	438	✓	✓	✓	✓
Manhattan Associates	188	✓	✓		✓
Epicor	163	✓	✓		✓
IBM	148	✓			
Descartes	140				✓
Infor	104	✓	✓	✓	✓
HighJump	92		✓		✓
GT Nexus	90	✓			✓
Kewill	81				✓
PTC	72	✓			
E2open	66	✓	✓		✓
Unit4	65		✓	✓	
Qunitiq	53	✓		✓	✓
IBS	52	✓	✓	✓	✓
IFS	52	✓	✓	✓	✓
Inspur Genersoft	51	✓			
Knaxis	50	✓		✓	
TOTVS	50	✓	✓		✓

Source: Modern Material Handling

Figure 76. Swisslog's Autostore



Source: Swisslog

Figure 77. Ocado's Smart Platform



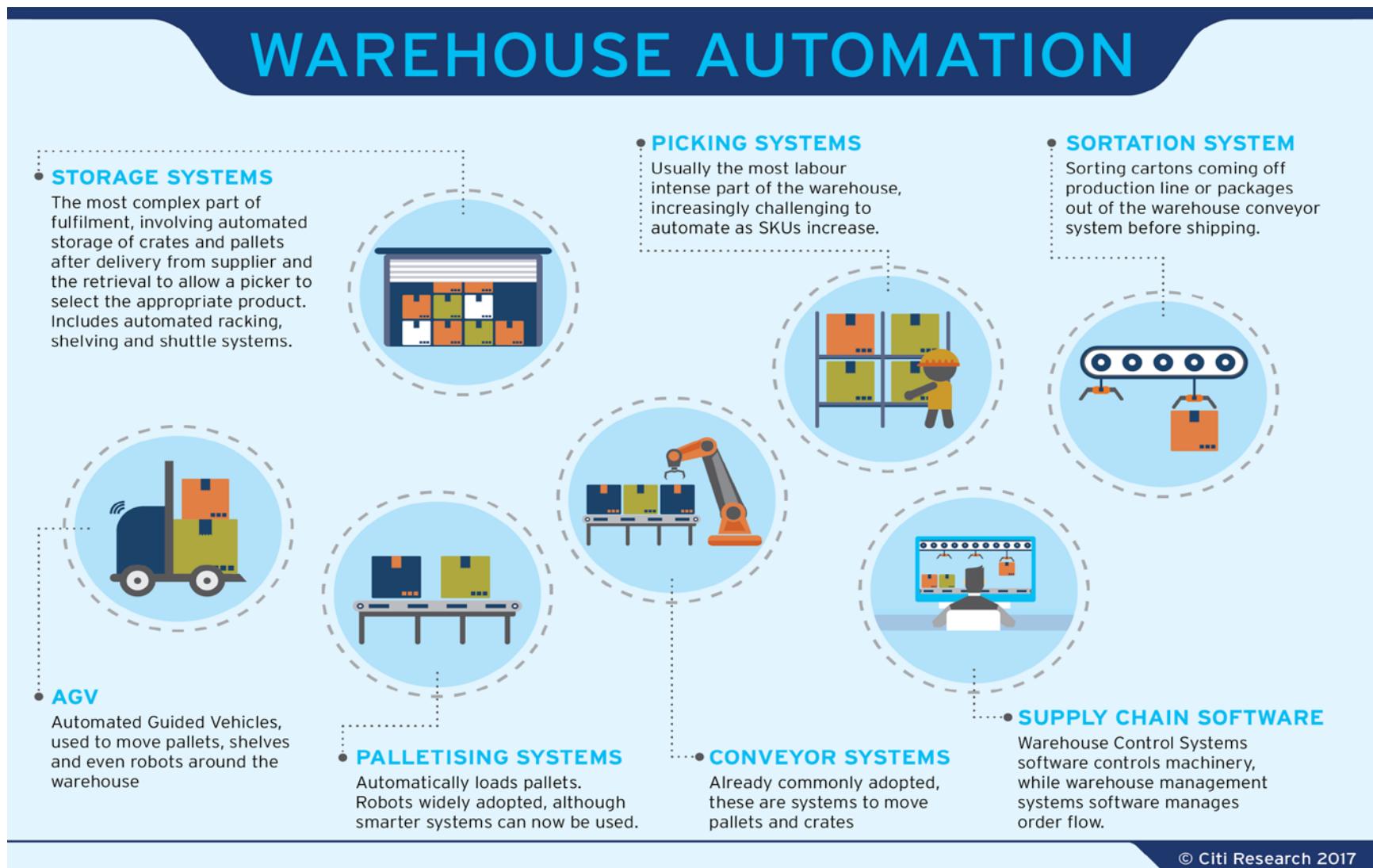
Source: Ocado

Why Automate?

Automation is arguably a cost of doing business: Same and next day delivery is not possible without it.

- **Throughput:** An investment in 2014 by online clothing retailer ASOS saw an immediate jump in units picked per hour from 55 units per hour to almost 120 units per hour, which is now approaching 160 units per hour. This increase in efficiency drives cost savings for the retailer.
- **Dispatch time:** In the above ASOS example, the average dispatch time was also reduced from over 3.5 hours to less than 2.5 hours. The decreases in dispatch times allow retailers to move to later cut-off times for next day or one day deliveries, thereby accessing a greater level of consumer demand.
- **Larger ranges of stock:** Efficient handling of stock allows greater volumes of product to be held. The success of aggregation websites shows clearly that a larger choice of products drives sales growth over time.
- **Cost reduction:** A combination of larger stock pools, 24/7 operations and faster delivery times has forced retailers to hire more staff in distribution centers, especially at peak seasonal trading periods. Adding automation can substantially reduce these costs and is a large driver of the investment put into these systems.
- **Cost of mis-picks:** A survey of 250 European supply chain and distribution managers across Europe by Kardex Remstar, a supplier of warehouse automation, found that distribution centers lose an average of nearly \$390,000 per year due to mis-picks. The cost of a mis-pick includes not only the cost of the item, but also other factors such as the expenses associated with shipping the item back, processing it upon receipt, returning it to stock, and loss of customer satisfaction. Kardex Remstar, an AS/RS provider, estimates that a mere 1% mis-pick rate within a 250-line warehouse with 3 SKUs per order would lead to a revenue loss of over \$1.5 million per year.

Figure 78. Inside Warehouse Automation



© Citi Research 2017

Source: Citi Research

Order Picking Remains a Robotic Challenge

As we noted earlier, order picking in warehouses still remains a largely manual process, with Amazon commenting that commercially viable automated picking remains a “*difficult challenge*”.

There have been launches of robots that enable automated order picking. Most of the robot vendors, as well as some of the warehouse automation players themselves, produce some variety of order picking robots. These order picker robots ‘pick’ the parcels off the pallet and place them into cartons or boxes, which go onto the conveyor system for further delivery.

Most recently however, albeit at a nascent stage, picking robots are being produced that are capable of picking objects off the shelf (which is a more subtle process), such as IAM Robotics which uses an autonomous mobile picking robot called Swift which has a Fanuc arm. These robots are often classified as collaborative robots (cobots), and the shelf-picking function often comes on top of being an automated guided vehicle, which transports objects from the shelf to the packaging and shipping corner of the warehouse.

Furthermore, Ocado has recently been evaluating the feasibility of the ‘SoMa project,’ which explores the robotic picking and packing of shopping orders in conjunction with its highly automated warehouses. Short for ‘Soft Manipulation’, the project is a European Union-funded program that aims to be fully implemented by 2020 and in collaboration with various research institutions across Europe.

Essentially what the project aims to develop is a gripper compatible with the existent industrial robot arm that is able to handle more fragile objects such as fruits and vegetables.

Figure 79. Order Picking is Still a Largely Manual Process

Category	Description	Considerations
Person to goods	Fulfillment center labor goes to shelf to manually select the product	Requires least initial investment Requires most labor to operate Ideal for low/medium throughput items Supported by identification technologies like RF, pick-to-light, or voice
Goods to person	The goods are brought to the worker through an automated storage and retrieval system, but individual items are then still picked manually	Moderate initial investment Improves labor efficiency Provides dense storage Ideal for large number of slow moving SKUs
Automated picking / dispensing	Sorters or robotic pickers select individual items	High initial investment Requires least labor to operate Required complimentary storage and replenishment systems Ideal for heavily accessed SKUs

Source: Citi Research, Dematic

Robots in the Warehouse

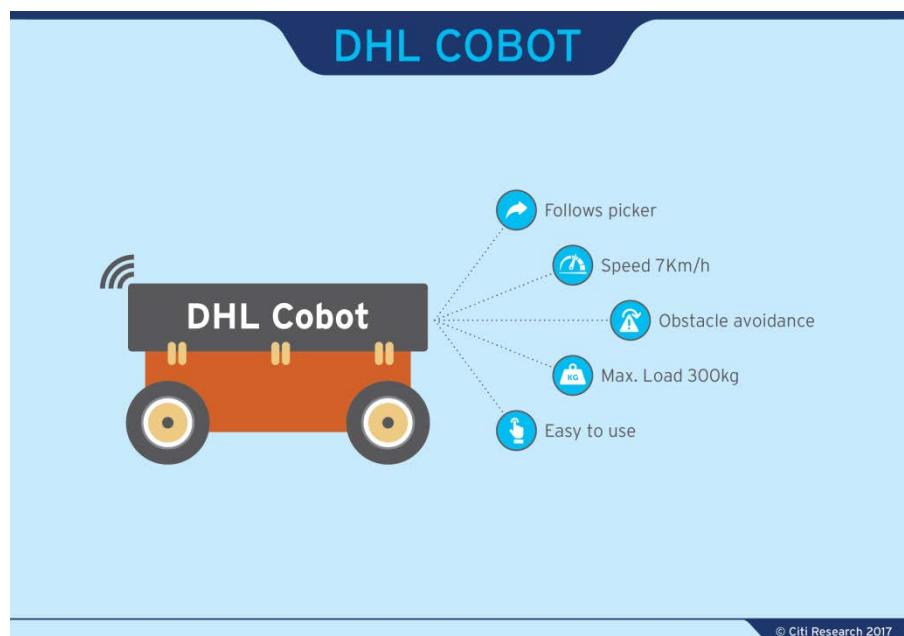
Robots to replace humans for stock and order fulfillment work are on the rise

According to the *Seattle Times*, Amazon’s installed base of robots grew 50% in 2016 to 45,000 units. These are largely its Kiva Autonomous Guided Vehicles. AGVs are largely used for the “goods to person” process we refer to above, and help minimize the walking of the employee to the goods – an Amazon warehouse employee could be expected to walk between seven and 15 miles per day while at work, according to a *Financial Times* report from 2013. According to IAM Robotics, “collectively in the U.S., companies employ 2 million people just to do stock and order fulfillment work.”

Warehouse robots are typically used for:

1. **De-palletizing/palletizing:** De-palletizing robots strip a pallet of products coming into a warehouse. In the simplest cases this can be all the same product (say from a single manufacturer), but may also contain mixed products. De-palletizing robots are typically standard industrial robots with a dedicated tool mounted, often using a vacuum enabled grip to remove packages from the pallet. Palletizing robots re-pack the pallet for onward shipment.
2. **Order picking:** A picking arm can be mounted to a standard industrial robot/cobot. As highlighted by DHL, a standard industrial robot from the major supplier has none of the five senses when it comes out the box, meaning the sensing/machine vision, software and dexterous tool are crucial add-ons.
3. **Goods-to-person movement through AGVs:** Autonomous Guided Vehicles are typically used for goods-to-person movement.

Figure 80. DHL's Cobot



Source: DHL, Citi Research

Figure 81. Palletizing Robot



Source: Dematic

Figure 82. Picking Robot



Source: Dematic

Figure 83. AGV



Source: Dematic

Only 10% of Amazon's fulfillment centers use its Kiva robots

Only around 10% of Amazon's fulfillment centers deploy its Kiva robots (those designated as "eighth generation"), although more automated generations are in the pipeline. Amazon bought Kiva robots in 2012 to further automate its own warehouses. Kiva, now renamed Amazon Robotics, focuses on only one part of the automation, largely around the picking process where automated guided vehicles (AGVs) bring shelves of products to staff, rather than staff going to the shelves. In 2015, ten of Amazon's 109 distribution centers globally were considered 8th generation – those with Kiva robots in use – suggesting that even at Amazon there is further automation to be rolled out. In a 2015 interview with Supply Chain Digest, Amazon said that it was working on a 9th generation fulfillment center, which would use even more advanced levels of automation, without specifying details.

Although palletizing is the main function of robots in the warehouse, there have been recent developments in expanding the range of automation within the warehouse, such as into more delicate processes like picking and packaging. DHL has recently ordered Rethink Robotics' key products Baxter and Sawyer to test for automated packaging and assembling within the warehouse.

AGVs are also becoming more and more common place in the warehouse for delivering the picked products to the packager (so the picker can save the efforts of walking around the warehouse) or, in the case for some (Amazon and KIVA AGVs for example) having the shelves brought directly to the picker.

Figure 84. Some of the Warehouse Automation Robot Players Outside Palletizing

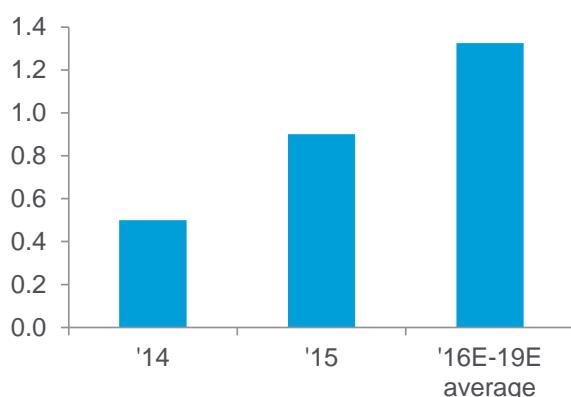
Company	Country	Cobot	Function	Comments
Amazon	U.S.	Kiva	AGV	Solely supplied for Amazon warehouses
Rethink Robotics	U.S.	Baxter/Sawyer	Packaging/ Assembling	In test phase of application for warehouses (order from DHL last year)
IAM Robotics	U.S.	Swift	Picking / AGV	Uses Fanuc arm
Swisslog	Germany	Autostore	Picking/AGV	
Locus Robotics	U.S.	LocusBot	AGV	Landed order with DHL
Fetch Robotics	U.S.	hmishelf/freight	AGV	
FIEGE Logistik	Germany	TORU	Picking/AGV	
6 River Systems	U.S.	Chuck	AGV	

Source: Citi Research

The logistics robot market is expected to grow to \$5.3 billion by 2019

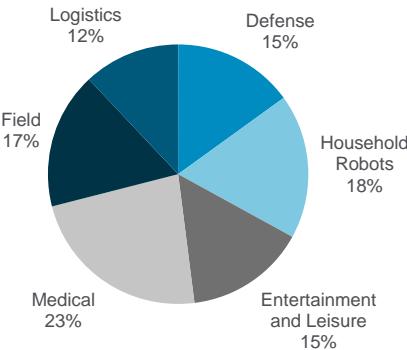
The growth of logistics robots (mainly AGVs) is expected to accelerate in the coming years. According to the International Federation of Robotics (IFR), the logistics robot market is expecting to grow from \$0.9 billion in 2015 to a total of \$5.3 billion over the succeeding four years, which implies a double-digit growth rate until 2019.

Figure 85. Growth in the Logistics Robotics Market (in U.S.\$ billion)



Source: IFR, Citi Research

Figure 86. Logistics Robots (typically AGVs) Account for 12% of all Service Robots by Value



Source: IFR, Citi Research

Data Capture

A sensor is a device that detects events or changes in quantities and provides a corresponding output, generally as an electrical or optical signal. Smart sensors can be attached to goods in a warehouse to enable automated inventory control.

ADC systems manage and utilize ever increasing amounts of data generated from automation technologies

Automated Data Collection (ADC), also known as Automated Data Capture, has become more complex and diversified over the years as automation technologies relate to exponentially increasing amounts of data, subsequently requiring more efficient ways to manage and utilize them. ADCs comprise of voice systems, radiofrequency identification (RFID), optical character recognition (OCR), radio frequency (RF) terminals, vehicle-mounted mobile computers, etc. One common technology in the ADC space is the bar code, in particular 1D and 2D bar code scanning, something we see during grocery shopping, for example.

RFID can identify and track tags and allows tags to be recognized through the packaging

In particular, RFID technology has recently come into the spotlight within the ADC space. RFID uses electromagnetic fields to automatically identify and track tags (in the form of granular chips) that are attached to objects. Compared to the traditional bar-code, which has the disadvantage of not being able to be detected when physically covered, the RFID detects radio frequency waves which allow tags to be recognized through the packaging.

We estimate the RFID market to be around \$10 billion (which includes all products related to passive/active RFID, including tags, readers, software, labels, etc.). The ADC markets were originally scattered with relatively small players (with differing players in differing products such as hardware, chips, etc.), but there are now two dominant players standing: Zebra Technologies and Honeywell. Although the portion of the market these two companies possess may vary depending on where the definition of ADC is drawn, an overview of positioning is shown below in Figure 87.

RAIN RFID Alliance

RAIN (RAdio frequency IdentificatioN) RFID solutions is a passive wireless system and is the fastest-growing segment of the RFID market, using a single, global standard. The alternative standard using a different frequency is called NFC (near field communication). Impinj, a leading provider of RAIN RFID solutions, says the market for RAIN RFID tags grew by a compound annual growth rate of 27% between 2010 and 2015 but that its own volumes grew by 36% from 2010 to 2016, to 6 billion units. According to the company, in 2017 endpoint IC (integrated circuit volumes will grow by over 30% year over year to around 8 billion units. From a different perspective, in 2016 its revenues grew 43% year over year, to \$112 million, with a further 47% growth in Q1 17 to \$31.7 million.

The RAIN RFID Alliance is an organization formed back in 2014 by four leading technology firms (Google, Intel, Smartrac and Impinj), with the purpose of promoting the adoption of Ultra high frequency (UHF) RFID technology. Since its launch, it has added prominent tech firms to its legion and currently has over 140 member firms, including Amazon, Datalogic, NXP Semiconductors, ST Microelectronics, Tyco International, and Zebra Technologies.

Figure 87. The Top 20 ADC Suppliers

Company	Revenue (2014, US\$m)	Barcode printers	Handheld Scanners	Stationery Scanners	RFID	Mobile Computers
Zebra Technologies	2,081	X	X	X	X	X
Honeywell	1,098		X	X		X
Datalogic	484		X	X	X	X
SATO	192	X			X	
Toshiba TEC	153	X			X	
Denso Wave	121		X			
Casio Computer Co. Ltd	90		X			X
Cognex	89		X	X		X
SICK AG	86		X	X	X	
Datamax-O'Neill	77	X				
Avery Dennison	68	X			X	
Fujian Newland	68				X	X
TSC Printers	56	X			X	
Bluebird Soft	51	X				X
NCR	50	X	X	X	X	
Unitech	45		X		X	X
Opto Electronics	43		X			X
M3 Mobile	38		X	X	X	X
Cipher Lab	36		X	X		X
Cab Produkttechnik GmbH	34	X				

Source: Citi Research, company data, Modern Materials Handling; Honeywell supplied RFID linked products only

The ADC space has seen enormous consolidation in the past decade, with three notable players that stand at the top of the table. The two leading players, Zebra Technologies and Honeywell, have particularly grown through a series of acquisitions in what was previously a very fragmented space. The most notable acquisition was Zebra's acquisition of Motorola Solutions' enterprise systems unit in 2014, where Motorola was the prior #1 player in ADC, especially in RFID. Honeywell's acquisition of Intermec also solidified Honeywell's standing as a leading ADC and RFID player.

Figure 88. The Acquisition Spree Consolidating the ADC Space

Company	Acquiree	Year	Deal Size (US\$)	Businesses
Zebra Technologies	Motorola Enterprise Systems	2014	\$3.4bn	Various ADC technologies
	Hart Systems	2013	\$94m	Cloud-based inventory management
	Laserband	2012	\$1.5m	Healthcare thermal printing
	Multispectral Solutions Inc	2008	N/A	Ultra wideband locating systems
	Navis	2007	\$145m	Terminal Operating Systems
	Proveo AG	2007	\$16.3m	Active RFID, RTLS
	WhereNet	2007	\$126m	Active RFID, RTLS
	Swecoin	2006	N/A	Thermal printing
	Retail Systems International	2004	\$7.8m	RFID smart labels
Honeywell	Datamax-O'Neill	2015	\$185m	Thermal printing
	Intermec	2013	\$600m	Various RFID technologies
	EMS Technologies	2011	\$500m	Mobile computing
	Metrologic Instruments	2008	\$720m	Bar-code scanners, mobile computers
	Hand Held Products	2007	\$390m	Bar-code scanners
Datalogic	Accu-Sort Systems	2012	\$135m	Auto-ID systems
	PPT Vision	2011	\$5.2m	Visual solutions
	Datasensor SpA	2008	N/A	Photoelectric sensors and devices
	Informatics	2005	\$23m	Barcode & RFID

Source: Citi Research, Company data

Recent Flurry of Deals in Warehouse Automation

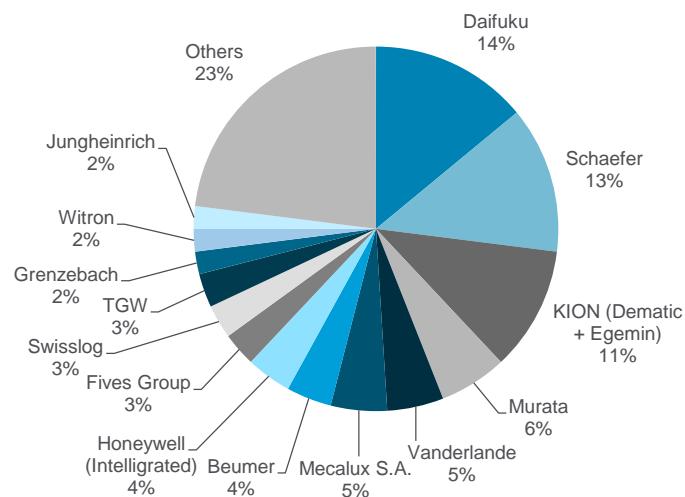
In 2017, Toyota Industries announced the most recent in a series of acquisitions of warehouse automation providers, through the proposed acquisition of Vanderlande, the #5 player globally. We estimate that the acquisition in combination with Bastian Solutions last February, moves Toyota Industries to the #4 position in Warehouse Automation behind Daifuku, Schaefer, and KION. Of the remaining top ten players, two are owned by larger industrial parents (Intelligrated and Swisslog) and the remaining four are privately held.

Figure 89. Warehouse Automation Companies Going Through a Streak of M&As

Announced Date	Acquirer	Target	Enterprise Value (EV) (EURm)	EV/Sales	EV/EBITDA	EV/EBIT	Sales (EURm)	EBIT (EURm)
Mar-17	Toyota Industries	Vanderlande	1,250	1.1x		22.3x		
Feb-17	Toyota Industries	Bastian Solutions	242	1.2x				
Jun-16	Honeywell	Intelligrated	1,327	1.7x	12.0x	-	796	-
Jun-16	KION	Dematic	2,876	1.8x	-	19.6x	1,593	147
Feb-16	KION	Retrotech	35	0.6x	-	-	62	-
Aug-15	Jungheinrich	MIAS Group	-	-	-	-	40	-
May-15	KION	Egemin	72	0.9x	-	-	76	-
Sep-14	KUKA	Swisslog	292	0.6x	-	17.2x	523	17
Aug-13	Daifuku	Wynright	-	-	-	-	81	-
Dec-12	Jungheinrich	ISA Group	-	-	-	-	-	-
Nov-12	Daifuku	Elite Line Services	-	-	-	-	-	-
Mar-12	Amazon	KIVA	605	-	-	-	-	-

Source: Citi Research

Figure 90. Warehouse Automation Global Market Shares



Source: Citi Research estimates, MMH, Jungheinrich, Honeywell

Figure 91. Global Warehousing Equipment Market



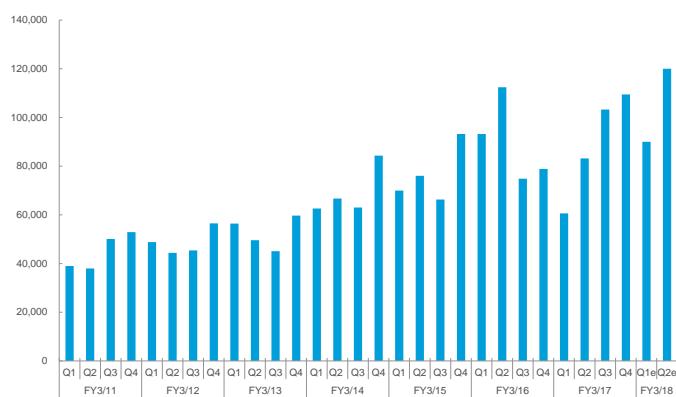
Source: Citi Research, Jungheinrich

Figure 92. Europe Warehousing Equipment Market



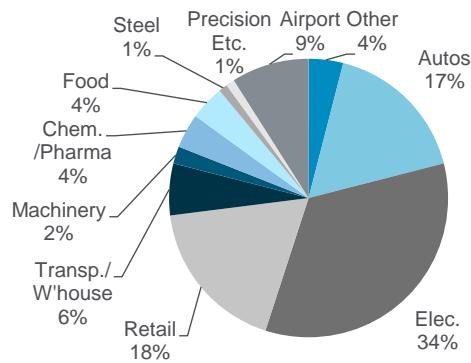
Source: Citi Research, Jungheinrich

Figure 93. Daifuku's Quarterly Order Trend (Yen mn)



Source: Company data, Citi Research

Figure 94. Breakdown of Daifuku's Customers (FY3/17)



Source: Company data, Citi Research

Warehouse and Delivery Automation in China – JD.com

In recent years, different Chinese e-Commerce or logistics players started to adopt more unmanned facilities to facilitate the logistics process. In particular, JD.com, the second largest e-Commerce player in China, invested heavily in unmanned warehouses, robots, and drones. According to JD, their same-day and next-day delivery service covered 1,410 counties and districts across China as of December 31, 2016.

Currently there are four types of warehouse robots in JD, namely (1) Automated Guided Vehicles (AGV) – reaching speed at 2 meter/second and can carry goods up to 300kg; (2) Six axis robots – with height around 2 meters and weighing 1.7tons, it can carry large items within 165kg and raise efficiency by 30%; (3) Shelf shuttle – highest speed without goods is 6 meters/second and can auto adjust its size according to the goods carrying, and (4) Picking and sorting robot Delta – 5x-6x faster comparing to human sorting, with highest speed up to once every second. It can sort small items within 5kg.

Apart from automation within warehouses, JD.com has also developed its drone delivery program since October 2015. According to JD, it has 40 drones in 7 models as of May 2017 and they can transport and deliver packages weighing 5-30kg and cover distances as far as 100km.

Figure 95. JD.com Asia No.1 Warehouse in Shanghai



Source: JD.com

Figure 96. JD.com Automated Logistics and Warehouse



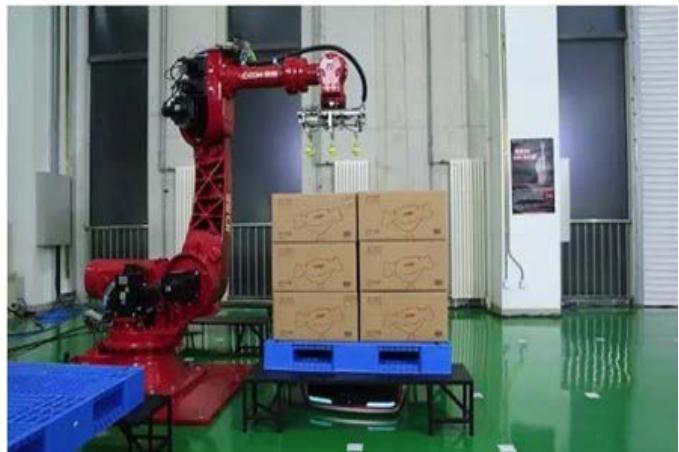
Source: JD.com

Figure 97. JD.com Automated Guided Vehicle (AGV)



Source: Donews

Figure 98. JD.com Six Axis Robot



Source: Tencent Tech

Figure 99. JD.com Shelf Shuttle



Source: Tencent Tech

Figure 100. JD.com Picking and Sorting Robot (Delta)



Source: Tencent Tech

Figure 101. JD.com Delivery Drone



Source: JD.com

Figure 102. JD.com Delivery Robot



Source: Sina Tech

Amazon the Disruptor

Jeff Bezos and his team at Amazon.com never sit still or settle for the norm. Combine that desire to innovate and disrupt with a north star of always focusing on the consumer and you get a company in Amazon that has put a tremendous amount of energy over the years behind making its operations more efficient through automation.

No other part of Amazon's business has seen more innovation in the area of automation than its fulfillment centers

Arguably no other part of Amazon's business has seen more innovation in the area of automation than its fulfillment centers (FCs), which are the cornerstone of the company's \$250 billion global retail business. Most of the product development work on FC automation is done out of the Amazon Robotics division, which was founded in 2003. Amazon Robotics is headquartered in North Reading, Massachusetts (a suburb of Boston), and has development centers in Westborough, Massachusetts and Berlin, Germany. A key milestone in the development of Amazon's robotics operation in general, and in the automation of Amazon's FCs in particular, occurred in 2012 when the company acquired privately-held Kiva Systems for \$775 million. Kiva's orange ottoman-shaped robots automate the picking and packing process at large warehouses that improves the efficiency of several of Amazon's FCs and reduces operating expenses by about 20%, according to Dave Clark, Senior Vice President of Worldwide Operations and Customer Service at Amazon.

Figure 103. Sample of Recent Job Openings at Amazon Robotics

TITLE	DEPARTMENT	LOCATION
Sr./Lead Quality Engineer - Robotics Hardware	Hardware and Advanced Robotics	North Reading, MA
Sr. Software Engineer - System Optimization	Software Engineering	Westborough, MA
Sr. Software Engineer - Machine Learning	Software Engineering	Westborough, MA
Sr. Software Engineer - Embedded Robotics / Middleware	Hardware and Advanced Robotics	North Reading, MA
Software Engineer - Autonomous Mobility	Software Engineering	North Reading, MA
Senior Software Manager - Machine Learning	Software Engineering	Westborough/North Reading, MA
Senior Software Engineer - Job Allocation Team	Software Engineering	North Reading, MA
Senior Software Engineer - Autonomous Mobility	Software Engineering	North Reading, MA
Senior Data Engineer	Software	North Reading, MA
Research Scientist - Research & Development	Robotics Systems & Solutions	North Reading, MA
Principal Machine Vision Scientist	Advanced Robotics	North Reading, MA

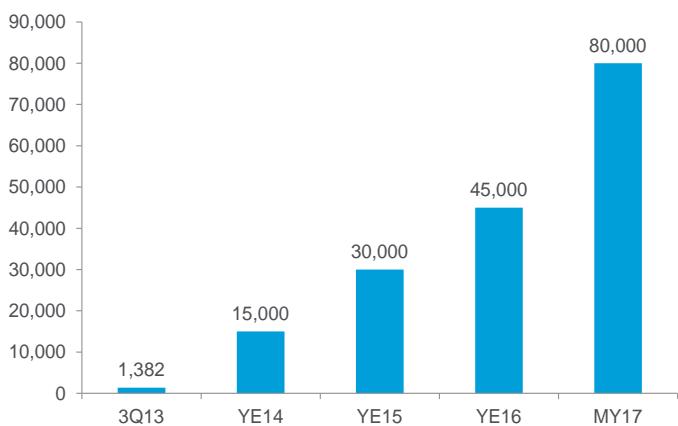
Source: Amazon, Citi Research

The Expanding (Accelerating) Role of Robot-Enabled Fulfillment

Amazon has increased the number of robots in its FCs and could have as many as 80,000 in operation

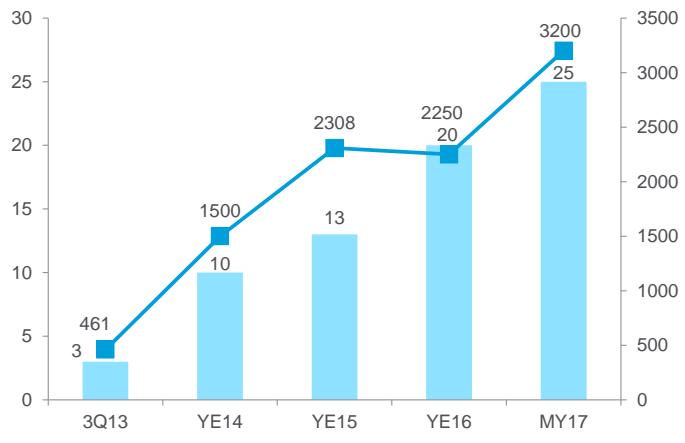
Since acquiring Kiva in 2012, Amazon has steadily increased the number of FCs using these robots as well as the total number of robots in operation. As shown in Figure 104, in late 2013 (about a year after buying Kiva) the company announced that it had nearly 1,500 robots operating in three FCs. That figure jumped to 15,000 in 10 facilities by the end of 2014, and since then has grown steadily by 15,000 per year. However, a recent press report suggests a significant acceleration in just the last 6–9 months, with the number of robots in operation potentially as much as 80,000 as of last month. In addition to retrofitting existing FCs to incorporate greater use of automation and robots, another driver of this increase could also be the large influx of new FCs in new and emerging countries (e.g., India, Australia, etc.).

Figure 104. Number of Robots in Amazon's FCs



Source: Citi Research, Company reports

Figure 105. Number Robot-Enabled FCs and Avg. Robots per FC



Source: Citi Research, Company reports

The Benefits of Automation/Robotics

Automation has increased stocking and order picking productivity and improved travel time for picking and restocking and quicker shipping times

There are many benefits to incorporating automation in general, and robots in particular, into Amazon's fulfillment operations. For instance, Amazon is able to increase stocking and order picking productivity. At its simplest level, travel time for both picking and restocking is significantly improved, especially as Amazon's FCs become larger (more distance/travel time required). It has been estimated that travel time can be cut by 50%–60% when leveraging Kiva robots. There are many other benefits. For instance, with the robots, Amazon can more tightly pack the shelves that hold items. Overall productivity gains have been reported to be as much as 2x–3x that as compared to pick-to-conveyor operations and 5x–6x as compared to manual pick-to-cart or pick-to-pallet FCs. Due in part to more robots in its fulfillment centers, Amazon has been able to drive down fulfillment costs and pass those savings on to customers. More-efficient FC operations also enable quicker shipping times. All of these efforts, ultimately, help Amazon distance its competitive lead and give consumers more of what they want — more selection, at good prices, with quick service.

There Is Still More Room for Improvement

It's unclear to what extent robots and automation will be leveraged in Amazon's operations. The company has stated that the number of robots used varies from warehouse to warehouse. One of the reasons is that an FC might have been built well before the time that Amazon began leverage robots and the benefits of redesigning the FC might not cover the cost. Another, more likely, reason is activity of a specific FC. For instance, Amazon operates some FCs just to handle large bulky items. The fact that Amazon is not leveraging robots in the majority of its FCs speaks to the opportunity for more advancement in robotics and automation technology. As stated on its Amazon Robotics website, "Commercially viable automated picking in unstructured environments still remains a difficult challenge."

That likely explains why this summer Amazon hosted its third annual Amazon Robotics Challenge, which rewards winning teams up to \$250,000 for inventing robots that result in demonstrable advancements in tasks performed by FC robots. This year the company chose 16 finalists for a tournament that will take place during RoboCup in Japan. The Challenge combines object recognition, pose recognition, grasp planning, compliant manipulation, motion planning, task planning, task execution, and error detection and recovery. The robots will be scored by how many items are successfully picked and stowed in a fixed amount of time. The competitors represent a diverse group of the world's leading academic institutions (teams come from Australia, Germany, India, Israel, Japan, the Netherlands, the Republic of Singapore, Spain, Taiwan, and the United States and from major institutions such as the MIT, Princeton, Carnegie Mellon University, University of Tokyo, University of Bonn, Chubu University, and Chukyo University).

Automation Beyond Amazon's Traditional Retail Operations

Beyond robotics, Amazon is looking to use AI and computer vision as well as new automation and robotics technology

The majority of Amazon's automation investment has centered on its retail fulfillment centers (i.e., its warehouse and distribution facilities). However, Amazon is also experimenting with new automation and robotics technologies to innovate other aspects of its traditional retail operations as well as looking at how automation, robotics, and machine learning can potentially enable disruption in altogether new markets. For instance, the company recently made its first official package delivery using a drone (in the U.K.). The company is also leveraging artificial intelligence (AI) and computer vision to better automate the operation of brick-and-mortar retail stores. At its Amazon Go store in Seattle, for instance, Amazon is testing a series of inter-connected technologies that automates the shopping and check-out process. Its perishable food operations, including Fresh, are also using AI and computer vision to identify and sort food based on shape, size, color, and ripeness. Chief Executive Officer Jeff Bezos has said that these computers are now better at identifying the ripeness of strawberries and bananas than a well-trained human. We believe technologies like these will play a role in how Amazon looks to disrupt the grocery shopping experience following the Whole Foods acquisition.

An Evolution in Grocery Picking

First Generation CFCs Based on Linear Conveyor Systems with Zone Picking

We can look at the example of U.K. online grocery firm Ocado to see the progression of automation in online grocery.

Ocado's first warehouse, Customer Facilitation Center 1 (CFC1) in Hatfield (about 6 miles north of the M25 (a London orbital highway), has evolved to include automated conveyors to route customer totes (crates) to pickers, and also to automate the storage and retrieval of slower-moving ambient items, resulting in an outbound pick rate of around 330 items per hour (or one item every 11 seconds).

Figure 106. Customer Totes (Crates) are Conveyed to Pickers with Stations in Auto-replenished Aisles, who Pick and Scan Items from the Immediate Vicinity of the Station (Zone Picking)



Source: Ocado

CFC2 in Dordon (about 15 miles north east of Birmingham) was commissioned in 2013 and uses the same conceptual approach as Hatfield, with customer totes routed via conveyors down a series of aisles to pick stations, with pickers selecting from adjacent "shelves" which themselves are automatically replenished from inbound goods, decanted and stored in high racking.

CFC2 was built to purpose using over a decade of learnings from CFC1

Dordon's CFC2 differs from Hatfield's CFC1 in that it was built to purpose using over a decade of learnings from CFC1, with an optimized layout and the latest hardware iterations. This resulted in an outbound pick rate for CFC2 we estimate to be around 390 items per hour, and at scale UPH (units per total warehouse labor hour) of 175 for CFC2 vs. 150 for CFC1.

Figure 107. Faster Pick Rates are Achieved by Using Automated Storage & Retrieval Systems (AS/RS) for Slow Moving Ambient SKUs (Picked from the Upper Green Totes to the Lower Orange in the Picture Below) ("Goods to Man" Picking).



Source: Ocado

Moreover, Ocado's first generation CFCs 1 and 2 use the same conceptual approach and conveyor-based system as the Webvan warehouses, built before its bankruptcy in 2001. However, in stark contrast Ocado operated out of a single site for over a decade with a clear focus on executing to meet customer expectations as its operations evolved. While Ocado has suffered the occasional mishap, it has produced very consistent delivery statistics.

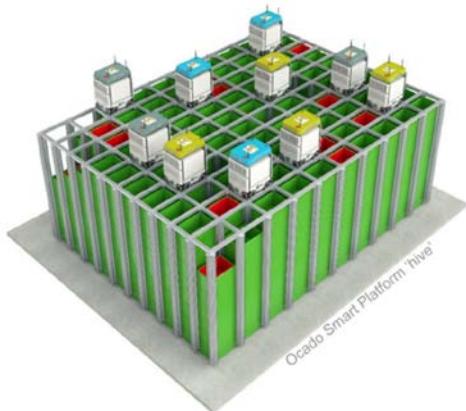
Nonlinear Second Generation CFCs "Rip Up the Manual" with the Introduction of the Hive & AGVs

In May 2013, Ocado announced a deal with U.K. supermarket Morrisons to launch and operate its online grocery offer using half of Dordon's CFC2 capacity. This enabled Ocado to accelerate the development of its Hive concept for its CFC 3 facility in Andover in Hampshire in the South of England.

CFC 3 is different from CFC 1 & 2 because of the use of bots and automated guided vehicles

CFC3 and the Hive represent a very different approach to fulfilling online grocery orders from the linear conveyor-based model of Ocado's first generation CFCs. Ocado's second generation of warehouses use robots (bots) or automated guided vehicles (AGVs) to move across a grid on top of a storage array, lifting and lowering totes containing customer orders or inventory to locations within the three dimensional grid.

Figure 108. Andover's CFC3 will Operate with Over 1,000 Robots (bots) to Deliver 65,000 Orders per Week at Full Capacity



Source: Ocado

Figure 109. Each Bot has the Ability to Carry a Tote Within its Chassis and to Lower or Lift Totes to or from Locations in the 3D Storage Grid



Source: Ocado

Ocado's proprietary bots perform multiple tasks within the Hive's operating model by carrying totes within their chassis:

- **Putting products away:** Goods from suppliers are decanted into white totes (shown as green in Figure 108) to enter the Hive via a Totes-In-Machine (TIM). Bots store the product by lowering the totes into a location within the three dimensional grid, such that totes are stacked on top of one another, using vertical guiderails.
- **“Digging”:** A bot will typically have to “dig” for a required SKU which has been stored and stacked beneath other product totes. As such, a digging bot will typically oscillate between two adjacent grid locations to reach and retrieve a required SKU. Higher volume lines will tend to be stored near the top of the stacks leading to an average “dig” removing between one and two other totes.
- **Goods to picker:** A bot will carry a product tote to the pick station. Human pickers pick items from the product tote, scan it, and place the item in a customer order tote.
- **Goods to storage:** After an item has been picked from a product tote it is lifted from the picking station and put away in the Hive. Empty inventory totes are removed by the bots, exiting the Hive via a Totes-Out-Machine (TOM).
- **Empty customer totes to pickers:** Red customer totes lined with three empty carrier bags sit within a white Hive tote. The totes are stored within the three dimensional grid, before being transported and lowered to a picking station, when required. As Andover ramps up its through-put, the site will install automated bagging machines, similar to the Group's established CFC2 in Dordon.
- **Completed orders to storage:** Customer totes typically stay at the picking station until the order is completed, at which point a bot will lift it away and lower it into a storage location within the Hive, pending its dispatch for delivery.
- **Storage to dispatch:** Ahead of loading a van for its route, customer totes are retrieved by bots, exiting the Hive via a TOM and transferred to the frame-loading used at both Hatfield's CFC1 and Dordon's CFC2.

Figure 110. At the End of June Andover was Operating with 300 Bots on a Single Picking Shift ...



Source: Ocado

Figure 111. ...Suggesting a Capacity Utilization Approaching 15% as the Facility Ramps Up



Source: Ocado

The bots operate over two separate grids for ambient and chilled goods. The one or two frozen items typically within an order are picked outside of the automated grid system.

Emerging Technologies

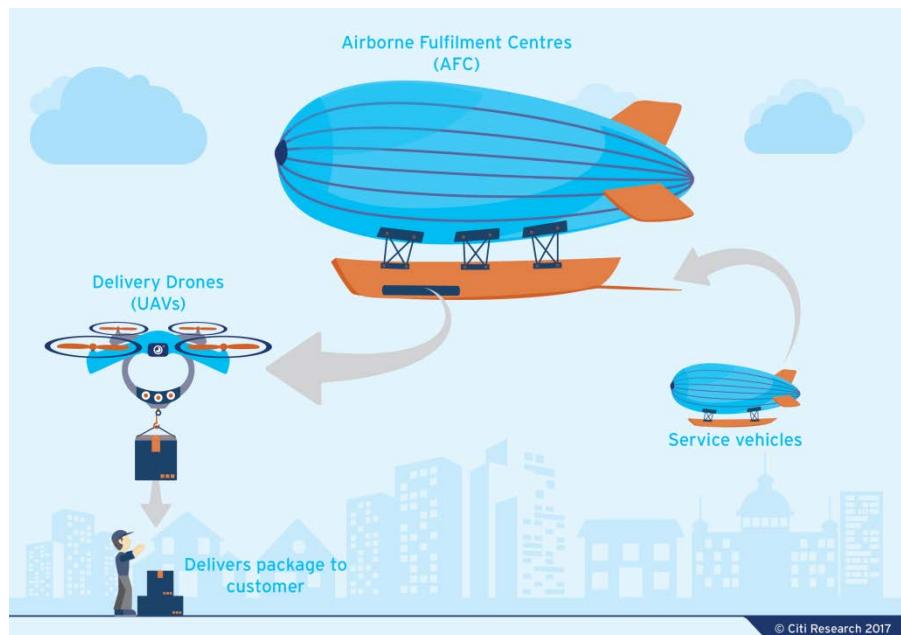
As technology advances, we've only just seen the beginning of the potential

We commented earlier that some seemingly obvious technology is only just now reaching commercial potential. Some is still very much on the drawing board. We examine a few examples below.

Amazon Flying Warehouse

Recent innovations are changing the nature of order fulfillment and logistics, and few would potentially bring about the change as dramatically as Amazon's flying warehouses. Amazon recently filed and was awarded a patent for a giant flying warehouse, or as Amazon puts it, the "airborne fulfillment centers (AFC)." The system involves the AFCs, which take on the form of a giant airship, staying afloat (with drones and goods onboard) at a high altitude and delivering goods to the nearby customers via the drones onboard while goods are replenished via supply vehicles.

Figure 112. Amazon's Flying Warehouse



Source: Citi Research, Amazon

Drone Delivery

Using drones (often referred to as UAVs, short for 'Unmanned aerial vehicles') for delivery is undergoing trial stages, with Amazon making its first drone delivery in the U.K. in December of last year. The drone delivery system is designed to deliver parcels weighing less than 2.27kg (~6 lbs) for flights taking under 30 minutes, with the first delivery including an Amazon Fire TV (essentially a tablet-sized portable TV set) and a bag of popcorn. Recently Amazon also conducted a demonstration of drone delivery in California, although it is unclear on when this will actually be implemented due to regulatory issues and debate on the method of delivery (direct drone delivery vs parachuting package from the air).

Warehouse Drones

Amazon is not the only one focusing on developing drones for automation purposes. Walmart introduced a system in June 2016 where drones would be used to check warehouse inventories. The drones would fly over the warehouse and photograph the aisles to check if the products were misplaced on the shelves or if they ran out, effectively reducing the labor intensive process of checking stocks around the warehouse. They also are looking to deploy drones in their stores, where the drone would retrieve a product from a non-public stock room and fly it over to a delivery area where the staff can retrieve the item, so as to assist store assistants and remove the burden of searching and carrying a product across the store.

The Impact on Real Estate

e-Commerce players have had to look for warehouse locations with close proximity to customers

With the focus shifting towards faster delivery to end customers, e-Commerce players have been pressured to not only enhance automation within the warehouse, but also to look for warehouse locations which enjoy proximity to the customers themselves (hence, cities). This has led to affect the real estate market, as the desire for location of the warehouses exceeds the land resources available. For instance, in the U.K., the mismatch between supply of and demand for warehouses along with political factors putting priority towards building new homes have caused warehouse rents to rise by 17% over the past six years in London and 11% in the broader South-East U.K., according to the Economist.¹

In Japan, the last few years have seen a sharp increase in new construction of large warehouses/distribution centers. According to Jones Lang Lasalle, in 2016 nearly 1.1 million square meters (sq.m.) of large-sized distribution centers (>10,000 sq.m.) were opened in Greater Tokyo, an increase of 7% year-over-year. In 2017, growth is forecast to be ~3%. The main driver of this demand growth is the e-Commerce sector, which required approximately 500,000 sq.m. of new space last year. As an example of what is being built, GLP plans to open a six building distribution complex covering 650,000 sq.m. by 2022 in Sagamihara, to the west of Tokyo, with a total investment of ~\$1.1 billion. The flip side of this expansion is growing vacancy rates in smaller, older distribution centers not located close to highway intersections.

The increasing adoption and deepening penetration of technology has had a profound impact on global property markets; however, the general consensus is that we are only on Day 1 of the seismic disruption that continued proliferation of e-Commerce and other technological advances will create.

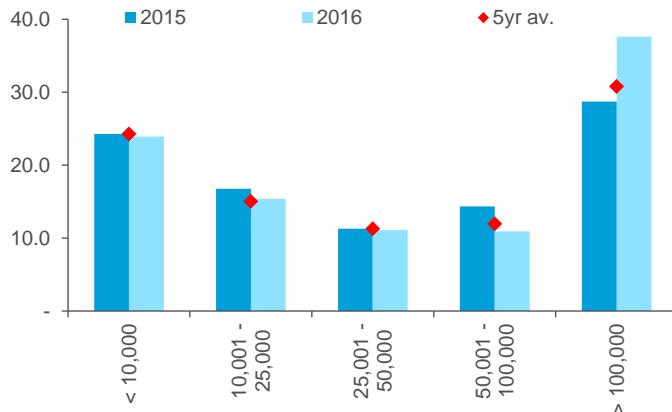
While we can be certain that advanced robotics, autonomous cars, big data, and 3D printing will drive changes in the way that businesses manufacture and distribute products and how consumers purchase those products, it is not yet definitively clear how such new technologies are permanently impacting site-selection processes for commercial real estate.

It has become apparent, however, that there is no uniform, one-size-fits-all solution that can be applied, which has driven a huge surge in demand for land and assets in strategic locations.

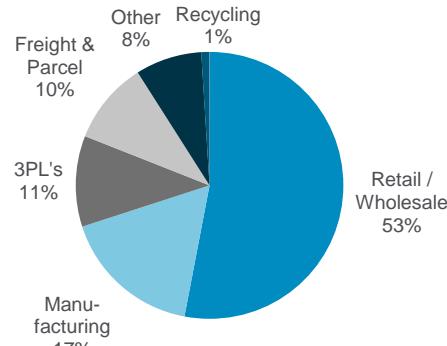
How technologies will permanently impact the site-selection processes for commercial real estate is still unclear

¹ The Economist, <https://www.economist.com/news/britain/21710271-britons-do-more-their-shopping-online-almost-anyone-else-move-cyberspace>

Figure 113. U.K. Take-up of Industrial Space in 2016 by Asset Floorplate Figure 114. U.K. Logistics Take-up in 2016 by Occupier Type



Source: Lambert Smith Hampton, Citi Research



Source: Lambert Smith Hampton, Citi Research

In the U.K. market, as highlighted by Figure 113, take-up of industrial and logistics space has been concentrated in first- and last-mile assets highlighting the dichotomy facing business between establishing nationwide hub-and-spoke models alongside urban presence to fulfill same-day delivery requirements, which are becoming increasingly prevalent.

Industrial real estate is evolving rapidly to meet occupier demand, albeit given the rate of current technological changes these demands are often extremely dynamic and fluid.

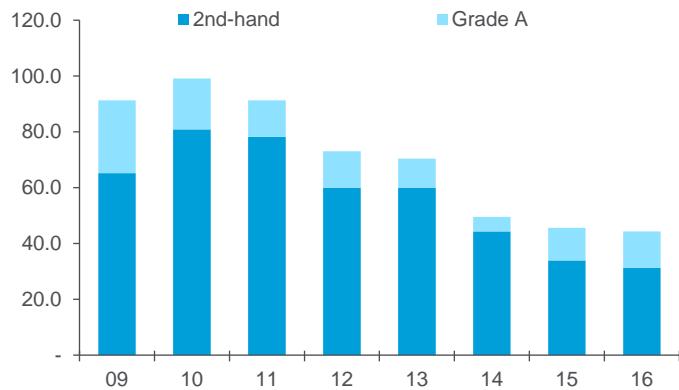
Figure 115. Real Estate Requirements for Modern Supply Chains and Delivery Requirements



Source: CBRE

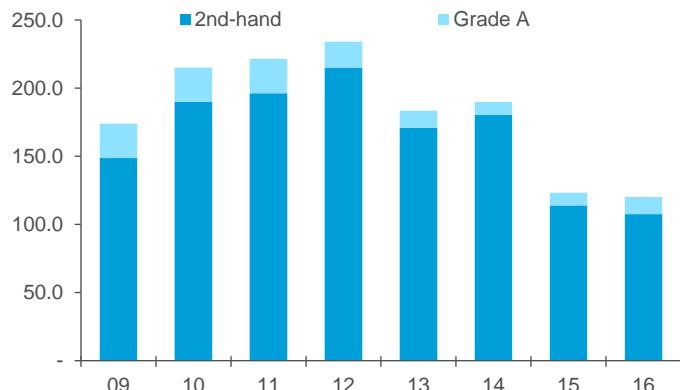
Industrial and logistics real estate has been the major winner from these trends since 2007/08, benefitting from robust and growing occupier demand, underpinned by the growth of e-Commerce (and in part traditional retail), expansion of third-party logistics markets, and muted development activity. Together this has created a perfect storm of rapidly growing demand and faltering supply.

Figure 116. U.K. First Mile (Logistics) Availability by Grade



Source: Lambert Smith Hampton, Citi Research

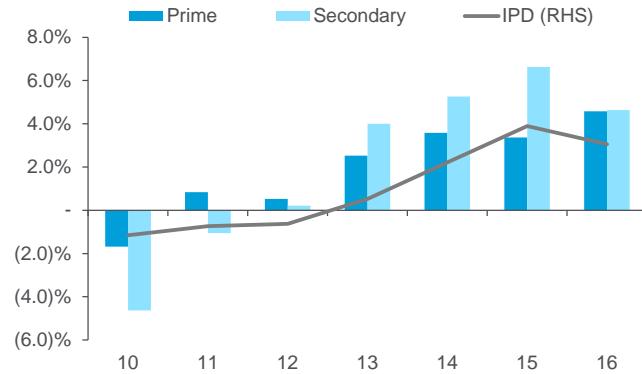
Figure 117. U.K. Last Mile Availability by Grade



Source: Lambert Smith Hampton, Citi Research

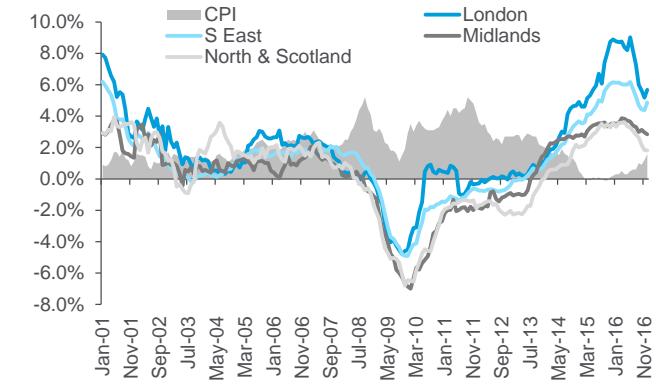
Figure 116 and Figure 117 above present data from U.K. property consultants Lambert Smith Hampton, demonstrating the significant erosion of availability in both the logistics (big box) and last mile (urban) markets.

Figure 118. U.K. Industrial Real Estate Rental Growth (%)



Source: Lambert Smith Hampton

Figure 119. U.K. Last Twelve Month Rental Value Growth vs CPI



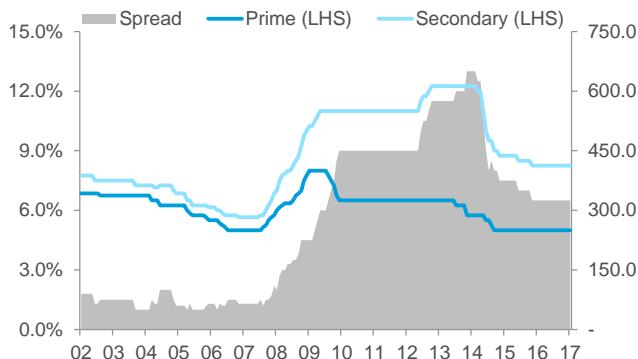
Source: CBRE

Continued occupier demand coupled with the erosion of supply led to the fourth year of meaningful rental growth across the U.K. industrial real estate market. Data from Lambert Smith Hampton, who track rents across 60 core industrial markets in the U.K., highlights that prime industrial rents increased by 5.3% in 2016 (versus 3.9% in 2015).

Rental growth for secondary industrial assets outperformed prime again in 2016 as the push towards last mile solutions accelerated alongside the widening loss of further swathes of light industrial and urban stock to higher-value uses.

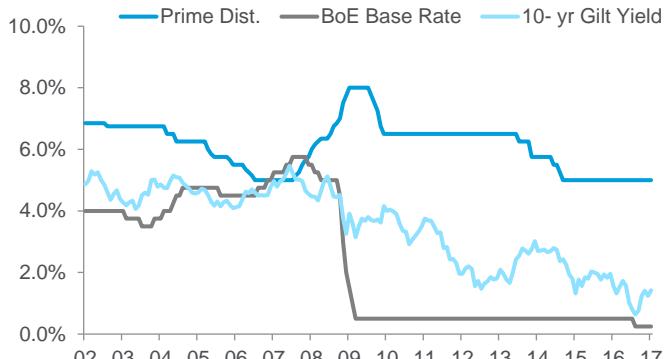
Figure 119 demonstrates how the above-target loss of industrial stock in London in particular has driven cyclically high rental value growth, with the spread to the Consumer Price Index (CPI) remaining historically wide at around 410 basis points. See comment on the specifics of the London supply and demand dynamics in further detail later in this report.

Figure 120. U.K. Distribution Yields and Spread (% bps)



Source: CBRE

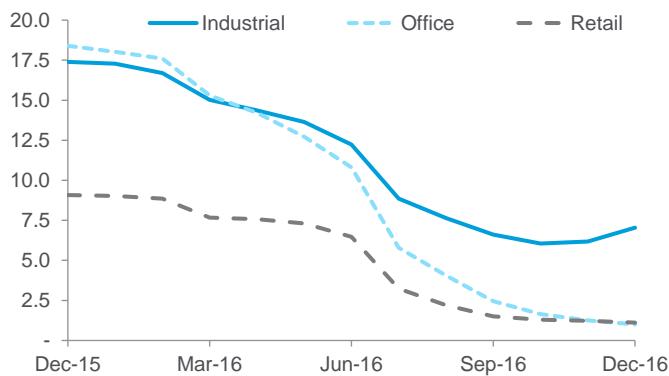
Figure 121. U.K. Distribution Real Estate Yields vs. Government Yields



Source: CBRE

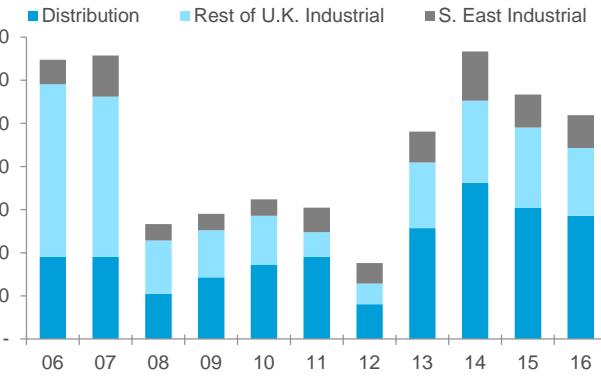
Yields on secondary assets have typically lagged movements in prime yields historically, as demonstrated by Figure 120. The evolution toward last mile could still drive late-cycle yield compression within urban industrial (mainly secondary) assets as the scramble for space accelerates, and currently the spread between prime and secondary industrial assets remains elevated at around 325 basis points versus 65 basis points in June 2007.

Figure 122. Total Returns in the U.K. by Real Estate Asset Class (%)



Source: MSCI, IPD

Figure 123. U.K. Industrial Investment Volumes (£ billion)



Source: Lambert Smith Hampton

Total returns for the industrial and logistics sectors in the U.K. have outperformed the other two core real estate classes of retail and office, and this is a trend that is consensually expected to continue as the sector continues to benefit from structural tailwinds.

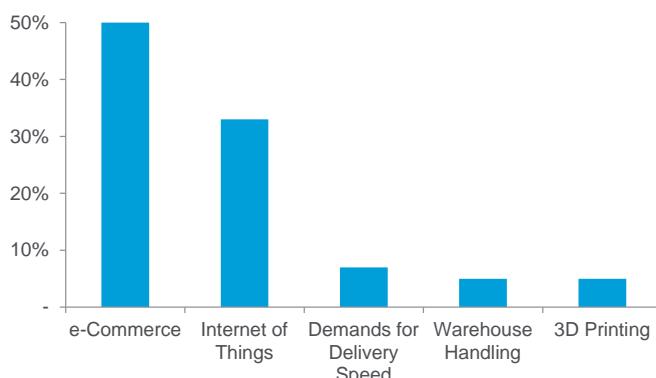
As a result, investment demand remains robust, with distribution assets accounting for the majority of investment spend, albeit overall volumes have been falling year over year since 2014 as the need for a cradle-to-grave logistics offering has helped drive up investment in more traditional industrial assets that can fulfill last-mile needs.

e-Commerce will Continue to Create the Greatest Disruption

The major disruptive force witnessed to date in real estate has been the deepening penetration of e-Commerce, which is consensually expected to continue to have the greatest impact on occupier decisions.

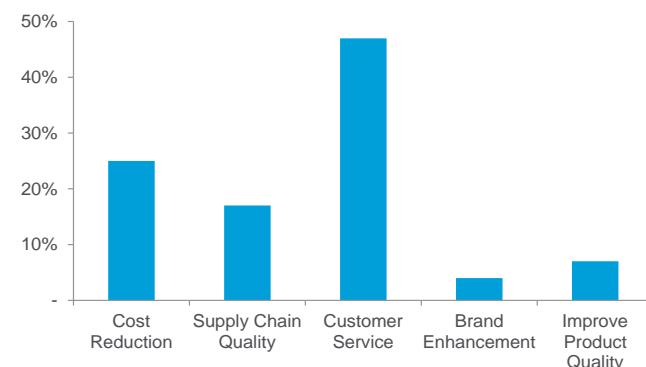
For the first time supply chains can be considered key differentiators for manufacturers and retailers, with the quickest, cheapest, and most reliable businesses capturing market share in the digital era.

Figure 124. Which Technology will have the Greatest Impact on Logistic Occupier Decisions in the Next Three Years?



Source: CBRE

Figure 125. What is the Key Driver of Innovation Impacting Manufacturing and Production?

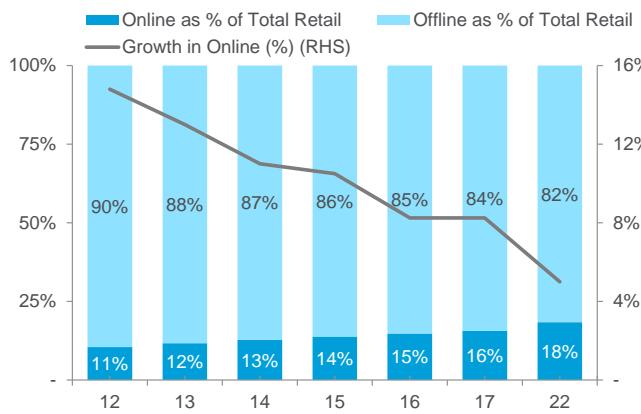


Source: CBRE

Figure 126 illustrates the evolution of online sales in the U.K. since 2012 and forecasts that while the growth in online spend (as a proportion of total retail spend) will fall to about 5% by 2021, e-Commerce will still represent (conservatively in our mind) almost 18% of total retail sales.

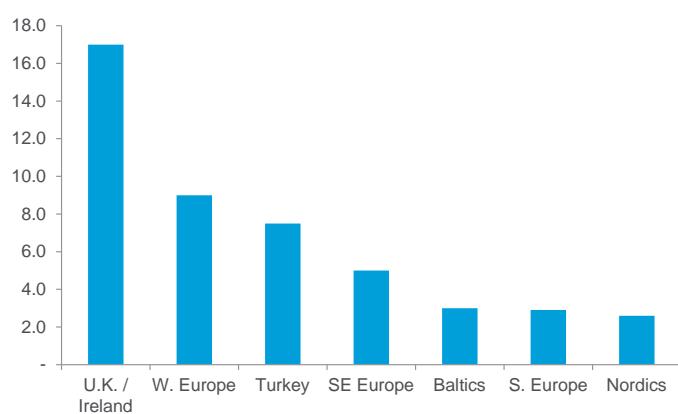
Assuming a growth rate of 5% per year, the U.K. has the largest annual space requirement in Europe, with estimates suggesting 17 million square feet of new logistics space is required every year between 2017 and 2021. For reference, Savills is currently tracking only 3.5 million square feet of development in the U.K. expected to reach practical completion in the next 12 months. (Figure 127)

Figure 126. Breakdown of UK Retail Sales by Channel and Online Growth



Source: Citi Research

Figure 127. Annual e-Commerce Space Requirement Through 2020



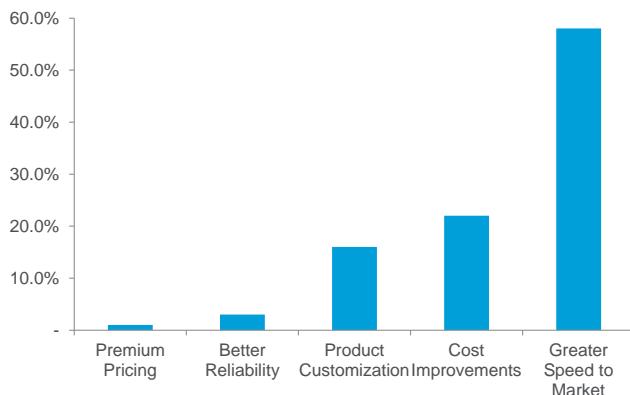
Source: Colliers International, World Bank, OECD

Customer need for instant gratification has introduced greater urgency and transparency into global supply chains

e-Commerce has introduced greater urgency and transparency into global supply chains, stemming from the increasing consumer need for instant gratification. People want more, they want it more quickly, and they want it more economically. Advances in technology and the adoption of automation therefore provide both opportunity and challenge to the real estate industry.

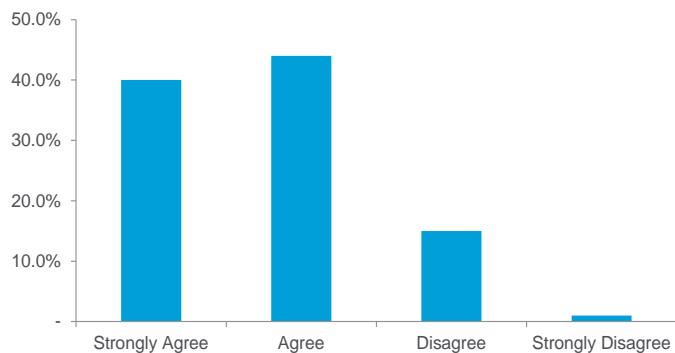
The real estate sector needs to be both innovative and responsive to the challenges that technology and automation create.

Figure 128. What Competitive Advantage Will These Innovations Bring?



Source: CBRE

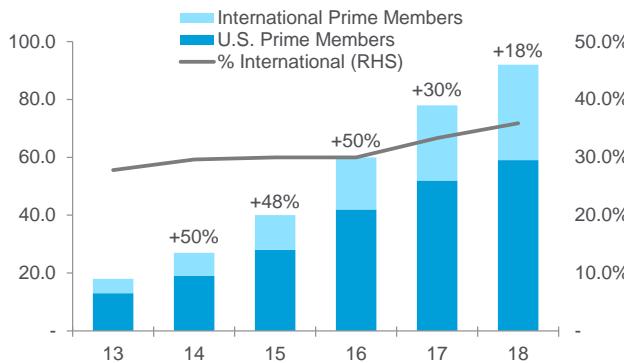
Figure 129. Will Technological Innovations Lead to Major Changes in the Location of Manufacturing [and Logistics] Over the Next Five Years?



Source: CBRE

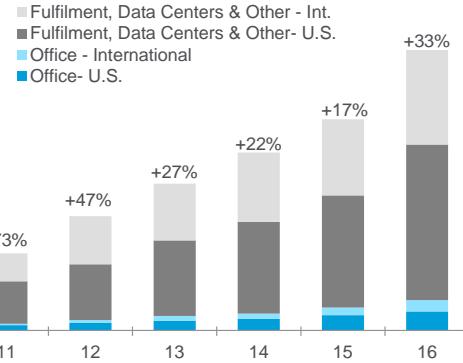
Greater speed-to-market is the overriding benefit that respondents to CBRE's "Power of Three" survey saw from deepening technological process, while almost 85% of the same respondents agreed with the idea that such advances will drive major changes in the location of manufacturing and logistics over the next five years.

Figure 130. Amazon Prime Membership Growth



Source: Amazon, Citi Research

Figure 131. Amazon Warehousing/Fulfillment Footprint Evolution



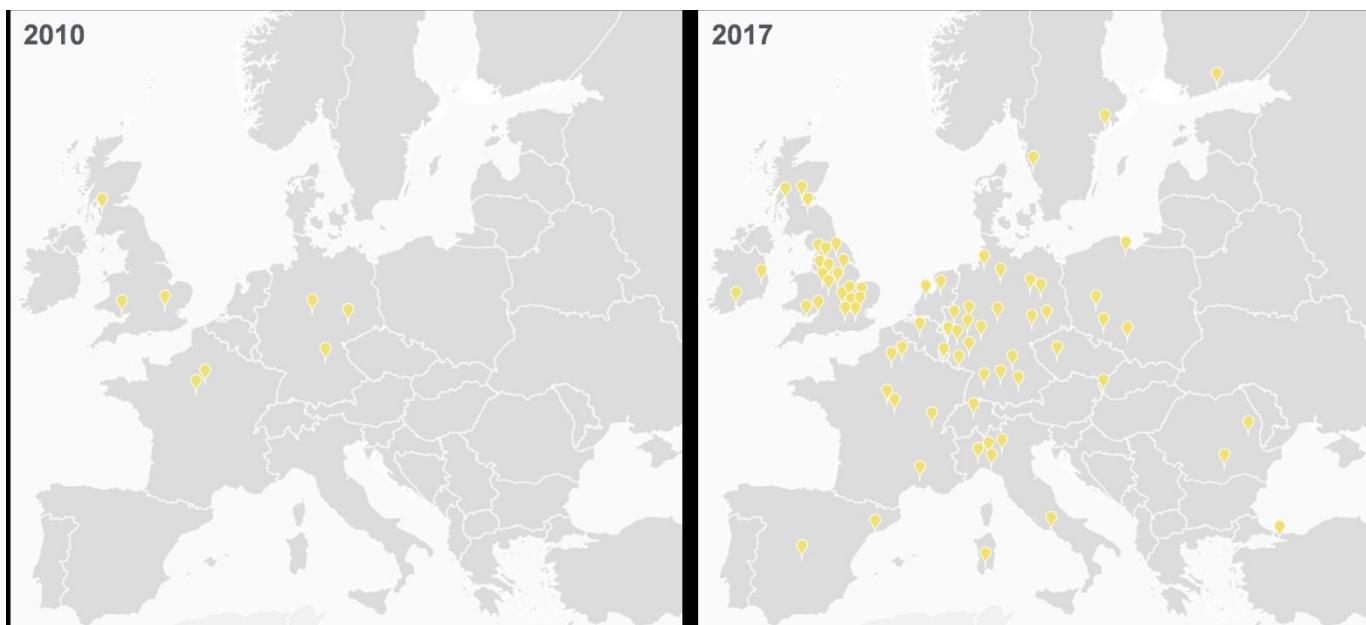
Source: Amazon, Citi Research

Amazon remains at the forefront of the accelerating evolution of e-Commerce, pioneering new innovations and operating models, which continue to influence and shape consumer behavior.

In the absence of a uniform industry solution, Amazon's investment in logistics and delivery infrastructure provides some indication to the extent of network footprint required to match Amazon's Prime (next day) and Prime Now (2-hour) service offering.

Between 2010 and 2016 Amazon increased its global fulfillment property footprint by 513%, from 26.1 million square feet to 159.9 million square feet, representing a 35.3% compound annual growth rate. Figure 132 below illustrates the European element of this proliferation since 2010 and highlights the geographic coverage the company now has across Europe.

Figure 132. Evolution of Amazon's Distribution Footprint between 2010 and 2017 in Europe



Source: Citi Research, Amazon.com (N.B. 2017 locations based on job vacancies posted on Amazon.com on 30 June 2017)

The introduction of Prime Now in 2015 and the aggressive roll-out of the subscription-based service, which now covers 30 U.S. cities, 9 U.K. and 6 European cities has led to an increased focus on last mile facilities, as demonstrated by the map above. An article in *The Telegraph* on April 15, 2017 estimated that Amazon is looking for a further 1,300 warehouse units across continental Europe to allow further roll-out of the market-leading Prime Now service.

What are the Main Technologies and How Do They Impact Real Estate?

In addition to e-Commerce, driverless vehicles, 3D printing and warehouse automation are all technologies which could impact global real estate markets

Beyond e-Commerce, there are three key technologies that are considered most likely to have the most impact on global real estate markets.

While these technologies are currently only in their infancy, real estate investors, developers, owners, and occupiers need to prepare for their full implementation in the real estate decisions they undertake today.

1. Autonomous (driverless) Vehicles

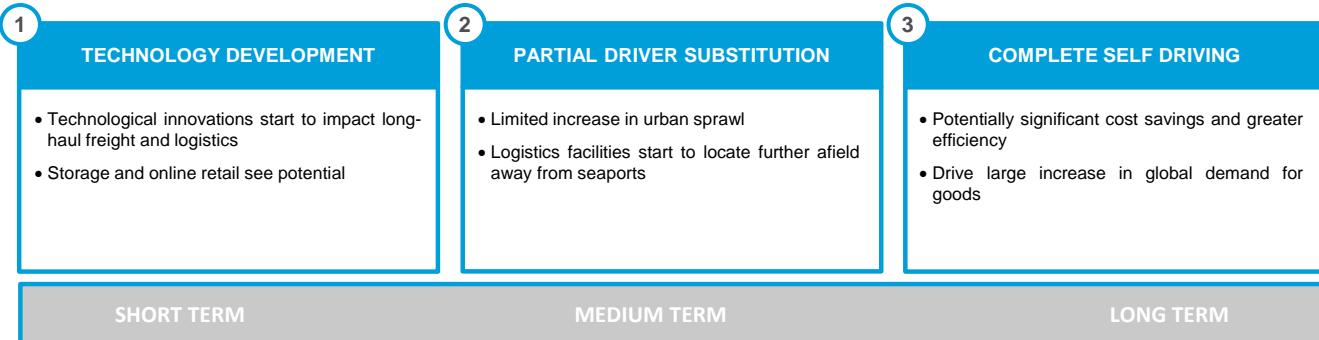
The onset of self-driving trucks will undoubtedly deliver seismic structural changes to both the global trucking and global logistics industries as the increase in range that the technology provides will fundamentally change how and where warehouses are located and operated.

The application of the concept of autonomous trucking centers around the opportunity created by operating small, partly automated truck convoys or platoons, in which trucks travel in close formation to reduce drag and save on fuel. Trucks within a platoon communicate with each other electronically and operate in coordination with the lead truck, accelerating and braking in unison.

By allowing trucks to travel closer together, at about 50–80 foot rather than the 160–240 foot recommended by the American Trucking Association for speed of 55mph, platooning technology offers fuel savings of up to 10% for each of the follower trucks according to Peloton Technology. It is estimated that platooning could therefore reduce fuel consumption in the U.S. truck industry by almost \$14 billion per year.

At present, U.S. truck drivers are only allowed to drive for 70 hours per week, the equivalent of ~3,000 miles, broadly a round trip from San Diego to Seattle. By removing these regulations, self-driving vehicles offer the potential to increase dramatically the range of coverage for a single vehicle and correspondingly across the entire fleet of logistics operators.

Figure 133. Timeline of Autonomous Vehicle Technology



Source: CBRE, Citi Research

In the U.K., the Department for Business, Energy, and Industrial Strategy has, alongside the Department for Transport, developed the Centre for Connected and Autonomous Vehicles, which aims to keep the U.K. at the forefront of innovation within autonomous vehicle technology.

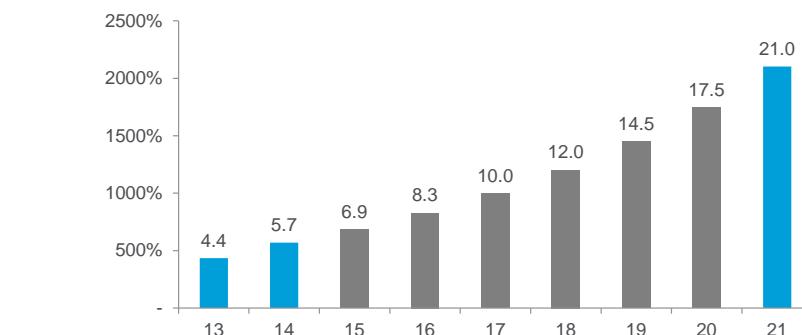
In 2016, Uber bought Otto, which has been trialing its autonomous delivery software (the first being a truck of Budweiser), raising the expectation that significant new disruption is likely to emerge within the trucking arena. In June 2017 Uber announced the integration of Otto into Uber ATG which will continue to drive the Group's self-driving program.

2. 3D Printing

The global 3D printing market is still in its infancy, accounting for just 1% of all U.S. manufacturing in 2016, but is considered to offer the potential to revolutionize global production and is likely to become particularly disruptive in certain industries like healthcare and hi-tech electronics. It is estimated that there are around 10 million 3D printed hearing aids in circulation currently.

Figure 134 illustrates research by CBRE performed in conjunction with UPS and the Consumer Technology Association, which forecasts that the global 3D printing market is set to grow rapidly, from \$5.7 billion in 2014 to almost \$21 billion by 2021, representing a compound annual growth rate of 21%.

Figure 134. Forecast Growth of Global 3D Printing Market (U.S. billions)



Source: CBRE, UPS, Consumer Technology Association, Citi Research

The key benefits of 3D printing are set out in Figure 135, which highlights the potential for the technology to (1) stabilize production costs; (2) help minimize cost-per-unit; (3) shorten lead times; and (4) reduce inventory holding costs through on-demand and just-in-time printing.

Figure 135. 3D Printing Offers Potential Opportunity to Mitigate Modern Supply Chain Challenges

#	Supply Chain Challenge	3D Printing Benefit
1	Parts are expensive to manufacture under traditional methods	Stabilize costs and minimize price-per-unit
2	Manufacturing processes can suffer from long lead times	On demand production helps minimize lead times
3	Inventory holding costs can be onerous	Facilitates just-in-time and on demand printing/production
4	Concentration of supply from one manufacturer	Reduces concentration risk associated with sole suppliers
5	Difficulty in becoming truly global	Parts can be made where and when required, even in remote locations
6	Import and export fees and tariffs can be punitively high	Helps minimize/eliminate import and export fees
7	Low functionality of existing parts	Facilitates design of new parts and products and repairs

Source: CBRE, Citi Research

As a result, 3D printing technology offers potential to dramatically reduce last mile delivery costs while also maximizing customer satisfaction from a fully flexible and shortened cycle time (from purchase order to delivery).

However, despite the opportunities that 3D printing offer for supply chain optimization through increased flexibility, improved quality and reduced cost, the overall impact on real estate is likely to be only moderate in the short term.

3. Warehouse Automation

Increased warehouse automation, aimed at ensuring the optimal balance between space, labor, equipment, and cycle time, will undoubtedly have much more far-reaching consequences on:

- The type, specification and configuration of real estate/property required by occupiers;
- The labor composition of new warehousing and distribution facilities; and
- Construction methods and the location of new facilities.

Analysis by The Boston Consulting Group forecasts that the use of advanced robotics will increase from today's 2%–3% to 25% by 2025 in a market that the International Data Corporation estimates will be worth \$135 billion by 2019.

In order to accommodate the increased level of technology, the following changes are expected to become (more) prevalent in factories and warehouses of the future:

- Taller buildings to accommodate higher bay racking and storage;
- Multi-levels (through increased usage of mezzanine floors) to maximize operational utilization of warehouse space while minimizing rental cost (rent it typically only paid on the ground floor of a big box unit);
- Longer and thinner design to maximize the quantum of loading bays for goods inward and goods outward;
- Incorporation of increased floor loading capacity to accommodate impact of robotics and mezzanine footprints; and
- New facilities which have ancillary office blocks and data centers to help manage the huge IT infrastructure and the storage and analysis of substantial amounts of data.

Figure 136 below summarizes how the specifications of e-Commerce buildings differ across the three broad industrial asset classes.

Figure 136. E-Commerce Building Characteristics

	Type	Site	Size (sqft)	Height (ft)	Parking / Yard	Design	Principal Activity
Urban logistics / last mile	Urban	•Within urban boundaries	<100k	16' or higher	•Truck-to-truck	•Dock & grade-level doors	•High velocity SKUs
		•Close to densely populated areas			•LGV cross-docks	•Open floor space	•<24hr storage
					•End-customer collection	•Showrooming	•Primarily transload ops
Mid-box	Metro	•Close to urban areas	<100–500k	24-36'	•Truck court 130'+	•1 dock door per 5,000 sqft	•Storage
		•Less densely populated areas			•Modest trailer parking		•Distribution
Logistics / first mile	Regional / National	•On key strategic transport routes	>500k	36-40'	•Truck court 185'+	•1 dock door per 10,000 sqft	•Order fulfillment •Reverse logistics •Breaking bulk
		•Established distribution locations			•Large trailer parking		•Diverse SKU storage & distribution
		•E.g. Golden Triangle, U.K.			•Large employee parking		•Pick & pack fulfillment •Reverse logistics

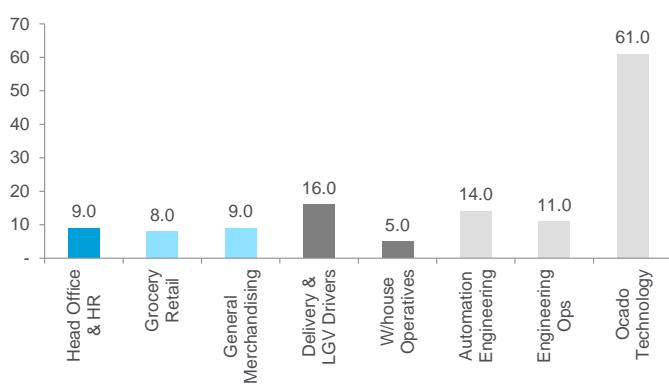
Source: Prologis Research, JLL

The Boston Consulting Group also estimates that the increased use of robotics has the potential to drive a 25%–30% reduction in average manufacturing costs, predominantly through the potential for savings in labor costs, which are currently estimated to account for 15%–30% of total supply chain costs.

However, robotics will not lead to totally automated factories, albeit the labor provision will become increasingly upskilled as highly trained employees will be required to maintain the robots and to make higher-level and strategic decisions.

This shift in labor composition is demonstrated aptly by Figure 137, which presents the current job vacancies at Ocado.com and highlights that 89 of the Group's 124 open positions are within engineering or in Ocado Technology, the robotic/software arm of the business focused on increasing automation.

Figure 137. Ocado Job Vacancies Highlight Focus on Automation



Source: Ocado.com, Citi Research

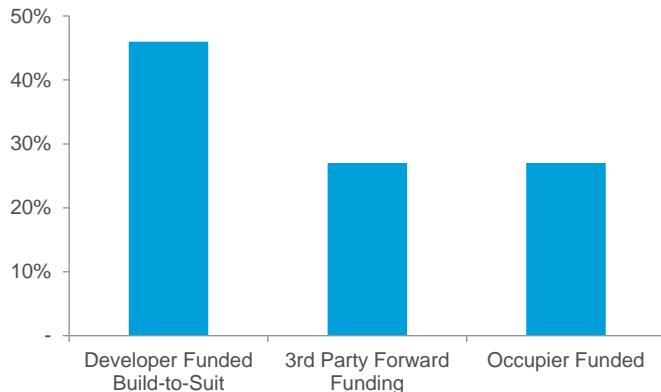
Figure 138. Boohoo.com Capex Spend Highlights Warehouse Investment



Source: Boohoo.com, Citi Research

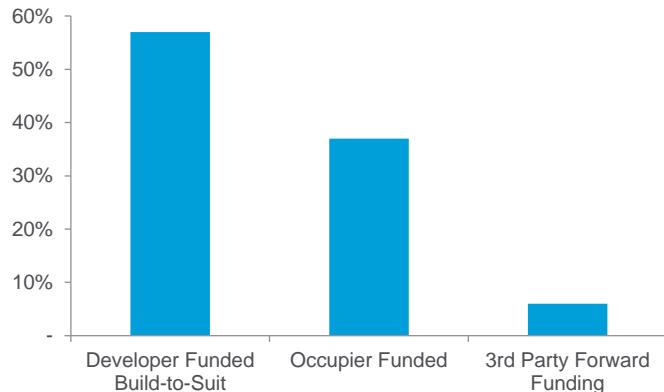
The final major area where warehouse automation is expected to impact real estate is through methods of construction and perhaps most importantly, the location of new facilities.

Figure 139. What is the Most Efficient Route for Delivery of New Manufacturing Buildings?



Source: CBRE

Figure 140. What is the Most Efficient Route for Delivery of New Logistics Buildings?



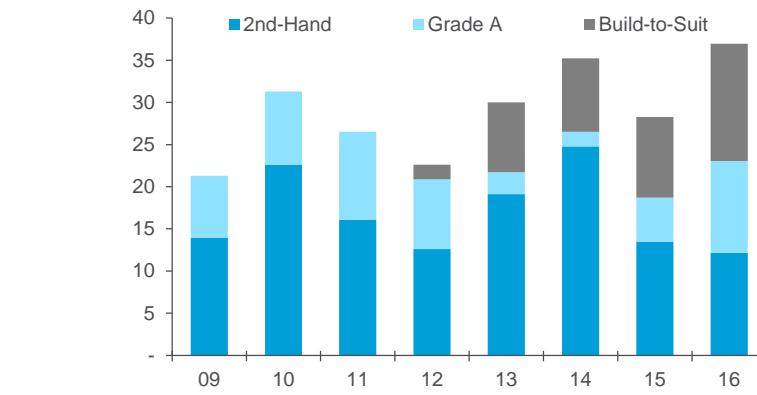
Source: CBRE

Survey results from CBRE, presented in Figure 139 and Figure 140, highlight the current preference among occupiers for build-to-suit product when seeking new manufacturing (46%) or logistics (57%) facilities.

Interestingly, 37% of occupiers voted 'self-build' as the preferred route for new logistics development, which appears to correlate to (1) the paramount importance of these assets to supply chains and correspondingly to brand reputations in modern markets; and also (2) the significant investment required in not only shed development but also the internal fit-out and automation of the facility. Anecdotal evidence in recent years suggests that it is becoming increasingly common for such fit-out costs to exceed build costs.

Figure 141 below highlights the emergence of build-to-suit development since 2012.

Figure 141. Analysis of U.K. Logistics Take-up by Asset Type (m sqft)



Source: Lambert Smith Hampton

Location, Location, Location

Land is finite in supply. Should the trend for re-urbanization deepen as is expected, the pressures on real estate allocation will intensify. Cities depend on the flow of goods and services, not only to residents but also to all of the offices, shops, hotels, and restaurants that service these residents, workers, and visitors.

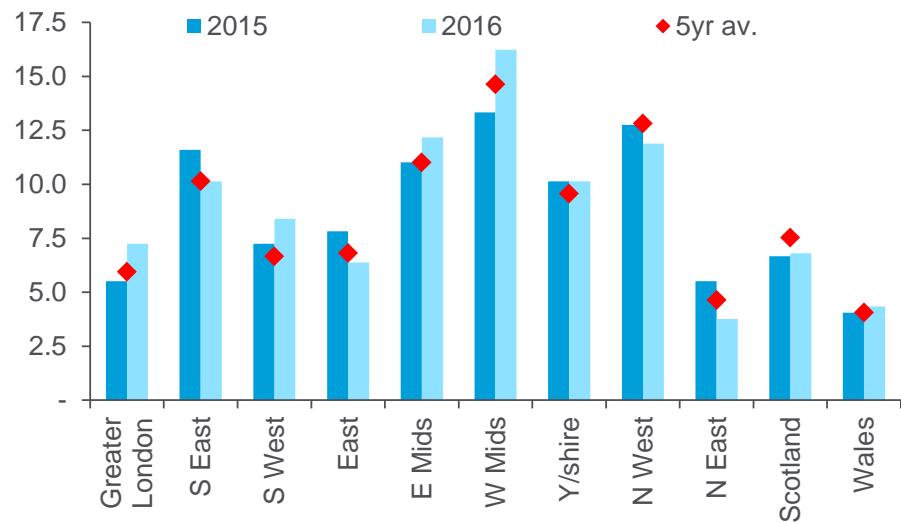
While increased automation largely targets minimizing cycle times (i.e., the time taken from order receipt until dispatch to customer), there are obviously subsequent factors after a product leaves the factory/warehouse that impact total delivery time. Proximity to market and end customers is therefore critical to retailers and manufacturers who want to ensure they can meet the growing demands for same day delivery.

Online fulfillment could require 300% more warehousing space vs. store-based fulfillment

Analysis by Prologis estimates that online fulfillment requires 300% more warehousing space as store-based fulfillment, which they quantify as being 800,000 square feet of additional warehouse space for every \$1 billion of incremental spend online.

Based on forecasts from Euromonitor for global e-Commerce growth, over 2.3 billion square feet of new warehousing space will be required by 2035; this equates to 3.5x the footprint of global logistics leader Prologis.

Figure 142. U.K. Take-up by Region (m sqft)



Source: Lambert Smith Hampton

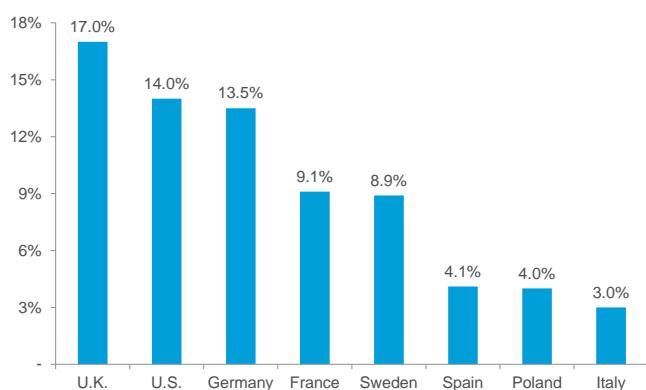
Figure 142 above presents U.K. take-up data from Lambert Smith Hampton and highlights four key areas where take-up in the U.K. increased in 2016 and remained above the five year average.

These areas all represent prime/core locations witnessing significant structural/secular demand growth and include Greater London, the South West (Bristol), and East and West Midlands.

As discussed earlier however, the U.K., given its position at the forefront of e-Commerce advancement (see Figure 143 below), is considered to require 17 million square feet of additional logistics space to be developed per year until 2021.

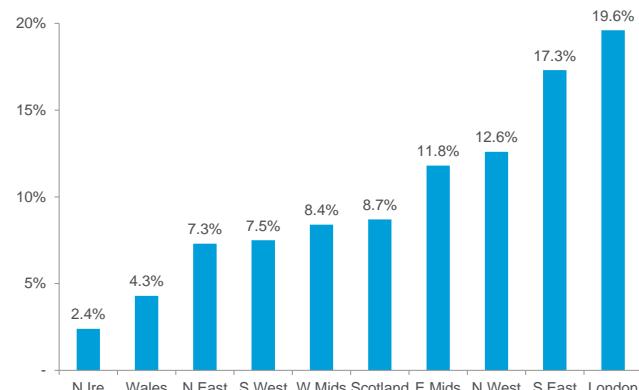
Perhaps unsurprisingly given the concentration of population density in London and the South East, around 37% of total parcel volume in the U.K. is delivered to addresses in these two areas.

Figure 143. The U.K. is at the Forefront of e-Commerce Advancement



Source: Citi Research

Figure 144. London & South East England Account for ~37% of all U.K. Parcel Volume



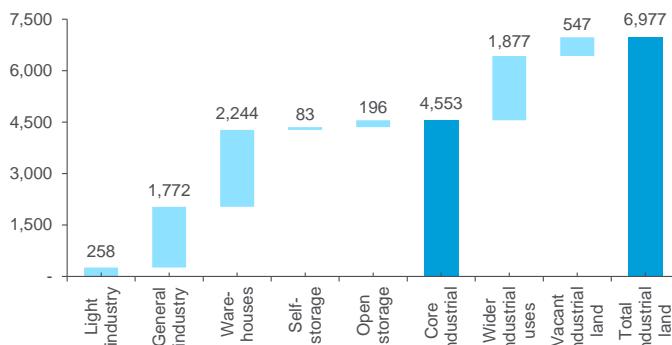
Source: Citi Research

Competition for industrial land between warehousing & distribution facilities from other higher-value land uses is fierce in London and the South East

The greatest requirement for last mile investment in the U.K. is within London and the South East. However London accommodates approximately 15% of the total U.K. population within an increasingly congested land area representing only 1% of the nation's land mass.

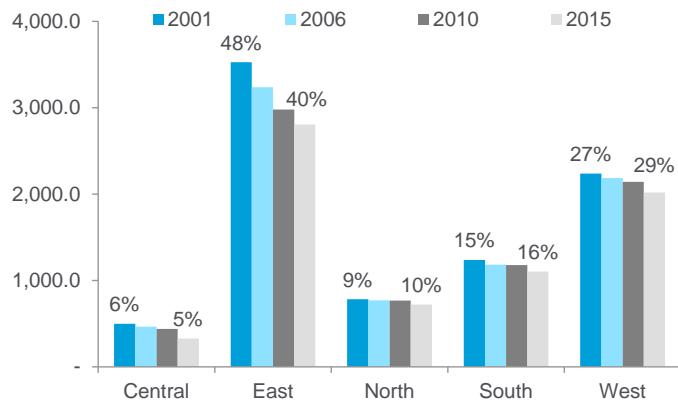
As such, the competition for low intensity industrial land for warehousing and distribution facilities from other higher-value land uses is fierce and with the population expected to increase by an additional 2 million people by 2030 (+24%), the pressure to convert industrial land into housing is accelerating.

Figure 145. London's Industrial Land Supply in 2015 (Acres)



Source: Citi Research

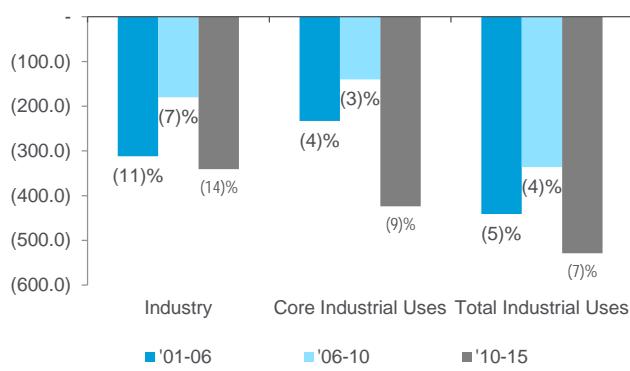
Figure 146. Central and East London Supply Eroding at Alarming Rate



Source: Citi Research

At the end of 2015 there was 6,976 acres of industrial land supply within Greater London, which represented a 16% erosion in total supply since 2001, driven by the release of industrial and employment zoned land for residential purposes. The majority of this supply has been lost from Central and East London, which saw their industrial land supplies reduce by 34% and 20% respectively since 2001.

Figure 147. London's Industrial Land Supply, 2001-15 (Hectares Lost)



Source: Citi Research

Figure 148. Pipeline Loss to Exceed 2031 Target by 553 Hectares

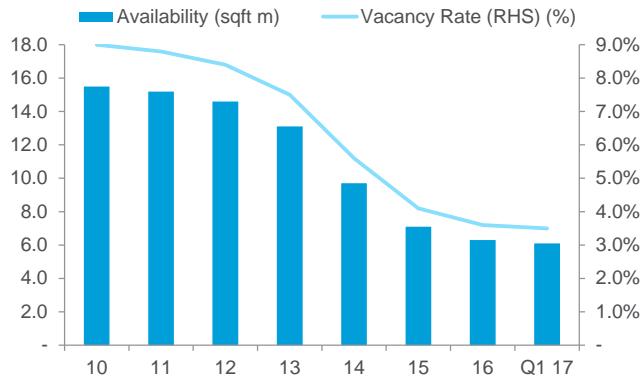


Source: Citi Research

The rate of industrial land loss in London is accelerating with the city currently losing 260 acres of industrial land per year, which if maintained will mean that the Greater London Authorities target release of industrial land by 2031 is exceeded within the next 12 months, 15 years ahead of schedule.

The current pipeline of release equates to 553 acres, roughly equivalent to the whole of London's flagship industrial zone at Park Royal...twice over.

Figure 149. London Industrial Availability (m sqft) and Vacancy (%)



Source: Colliers

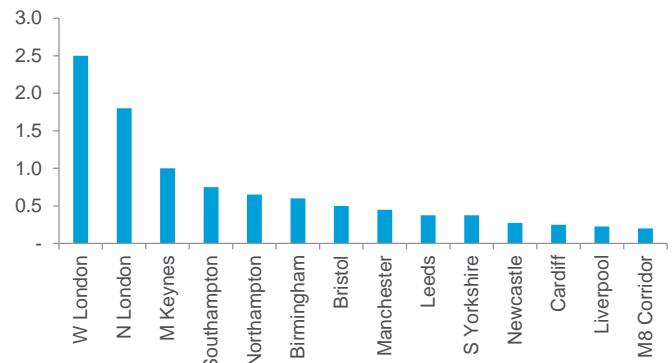
60%–70% of industrial sites brought to market in London in the last 1–2 years were lost to residential development

Anecdotal evidence from Colliers, an international property consultancy, suggests that 60%–70% of all the industrial sites brought to market in London over the last 12–24 months were ultimately lost to residential development.

This demand has led to a substantial erosion of availability (see Figure 149) alongside rapid land cost inflation in recent years (see Figure 150), with values in West and North London up by 11% and 38%, respectively, over the past 24 months.

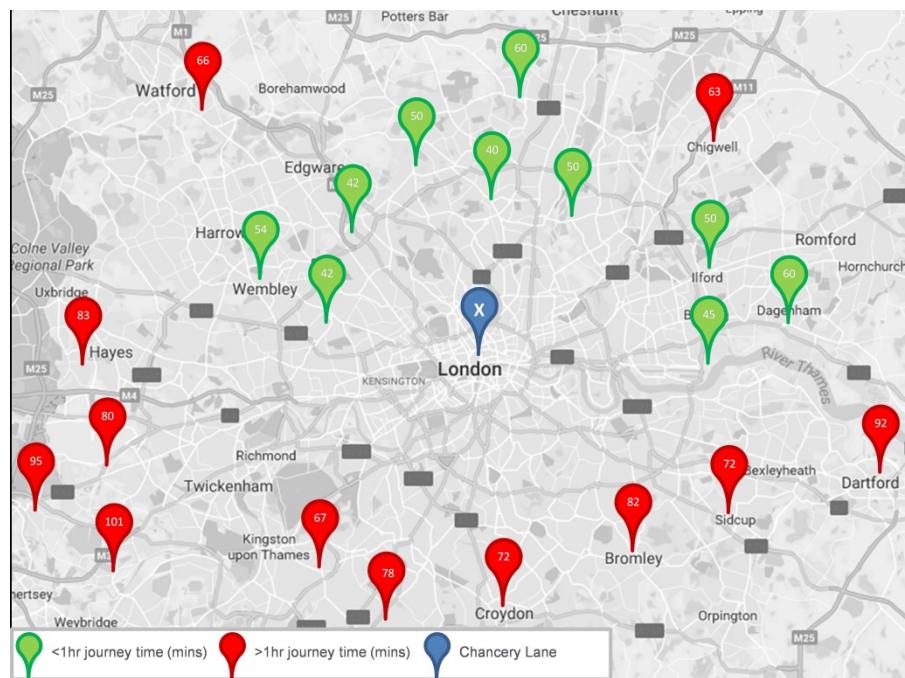
In attempting to determine suitable future locations for last mile delivery sites in London, we analyzed peak rush hour delivery times (by car) from various known and potential industrial sites to the city center, presumed to be Chancery Lane, W1.

Figure 150. U.K. Land Values per Acre, end 2016 (£'m)



Source: Lambert Smith Hampton

Figure 151. Delivery Times to Chancery Lane at 8am



Source: Citi Research, Google maps

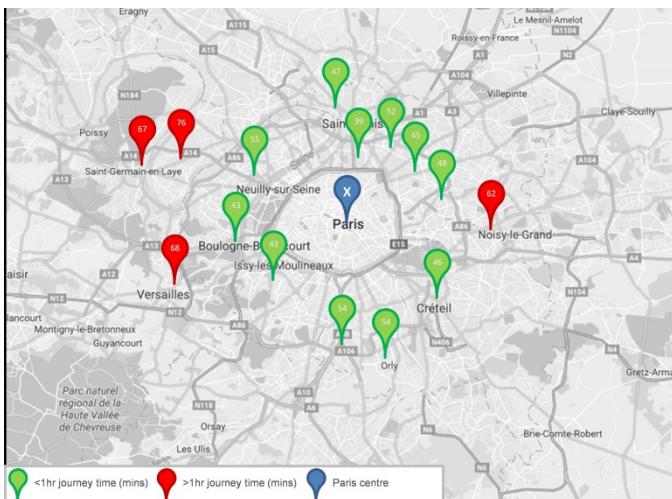
The best located industrial zone for a less than one-hour delivery times to the center of London are in expensive areas

As illustrated by Figure 151 above, Park Royal is the best located industrial zone in London, offering close proximity to the center of London, with delivery times at peak rush hour of about 42 minutes, equating to a journey speed of around 19km/hour. The average journey time across all of the sites tested was ~20km/hr.

However land in Park Royal is expensive, with current land values for fully-let land in Segro's book valuation of gross lettable area at £10 million per acre (\$13 million). Development land is closer to about £3 million per acre (\$3.9 million). Rental costs are also high at £10.50 to £15.50 per square foot, and availability is low at around 5.6%. Our analysis suggests that occupiers, investors, and developers can get similar connectivity from Barking in East London, where it was possible to travel into central London in about 45 minutes in rush hour, with an average speed of 25km/hour.

Land in East London is also substantially lower than in West London, at £1.5 million per acre (\$1.9 million), while rent is about 40% lower at £10 per square foot (\$~13/sq ft) with better availability of stock on offer.

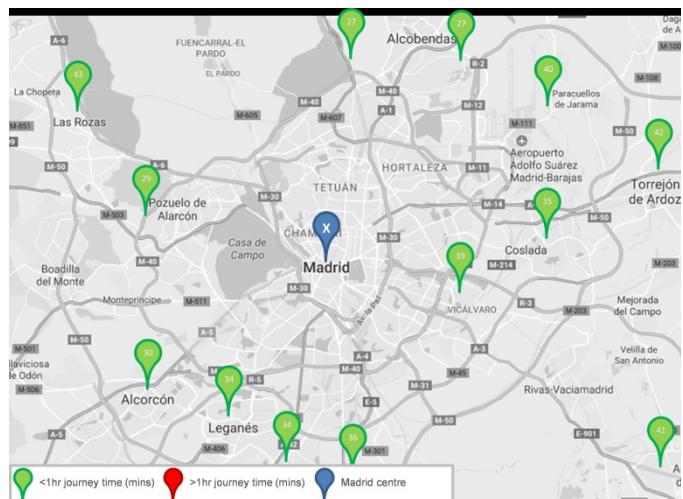
Figure 152. Delivery Times to Paris City Center at 8am



Source: Citi Research, Google Maps

Last mile facilities can be closer to the center of the city in Paris and Madrid

Figure 153. Delivery Times to Madrid City Center at 8am



Source: Citi Research, Google Maps

We performed similar analysis for rush hour deliveries in both Paris and Madrid and present the results in Figure 152 and Figure 153, respectively.

In summary, to meet a one-hour bilateral delivery deadline in Paris, a last mile facility would have to be located within 16km of the city center, given an average journey speed of 16.3km/hour at rush hour on the day of testing.

Traffic congestion in Madrid appears to be much lower with average journey speeds of 35km/hr essentially allowing for sub-1 hour deliveries from anywhere within the city, providing the widest scope for the location of last-mile facilities.

Focus on the U.S. Real Estate Market

Vacancy rates are at lowest levels on record in the U.S. while average asking rents are at all-time record highs

The industrial market in the U.S. is currently comprised of 15 billion square feet of standing warehouse stock.

Vacancy rates on a national level stand at ~5.4% — the lowest rate on record despite 55 million square feet of new supply completing in the first quarter of 2017. Some markets like Los Angeles are as tight as 0.9% while Phoenix at 10.0%, according to Newmark Grubb Knight Frank.

Average asking rents are ~\$6.10 per square foot, an all-time record for the country (not adjusted for inflation). Twelve markets posted double-digit rent gains of the past four quarters, led by Seattle with a 17.2% increase. Raleigh-Durham, Dallas, Austin, and Nashville rounded out the top five gainers. No market saw an outright decline in rents over the past four quarters. With new development slated to decrease slightly in 2017, vacancies will likely continue their downward trend and put further pressure on asking rents.

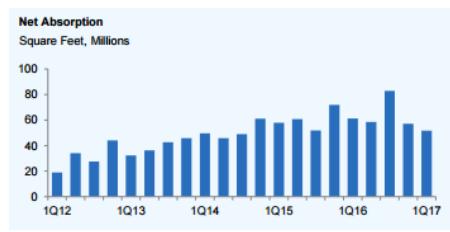
Product under construction declined from its record levels at year-end 2016 to 198 million square feet in the first quarter, according to Colliers. Key limiters to new supply include limited entitled land parcels, a controlled construction lending environment, higher pre-leasing thresholds especially amongst the public players, and labor supply constraints.

Figure 154. U.S. Industrial Asking Rent and Vacancy



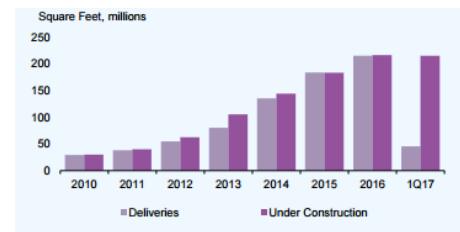
Source: Newmark Knight Frank

Figure 155. U.S. Industrial Net Absorption



Source: Newmark Knight Frank

Figure 156. U.S. Industrial Construction and Deliveries



Source: Costar, Newmark Knight Frank

Emerging Real Estate Innovations

We examine below some emerging innovations and concepts that have the potential to significantly impact real estate markets, from the integration of industrial and residential land uses in significantly land constrained markets to the development of vertical warehouse solutions and even towards flexible warehouse solutions along the lines on AirBnB.

Sheds with Beds

As discussed earlier, London is witnessing a rapid/uncontrolled erosion of its industrial land supply as local authorities battle to release sufficient land to meet targets for housing delivery.

Mixed-use schemes with industrial and residential uses is increasingly popular

As a result, the competing market pressures within real estate markets are forcing a re-evaluation of (1) strategic industrial locations; and (2) mixed use developments. Historically, mixed-use schemes have been between retail and residential uses rather than industrial and residential however given the current unprecedented demand for urban logistics infrastructure, ground-breaking new proposals are being considered.

The scheme between Travis Perkins and Unite Students in St. Pancras aptly demonstrates the concept of mixed use developments blending residential and industrial usage.

Given the unabating need for greater supply of affordable housing in cities, it is likely that similar schemes emerge more frequently, albeit such progress will require a greater shift in focus from local planners.

Segro, the FTSE 100-listed industrial REIT, is championing the sheds-with-beds concept and is developing two pioneering schemes in London in an attempt to tackle the land supply shortages in the city.

1. **Hayes, Middlesex** — Segro will build 250,000 sqft of urban logistics alongside 1,100 homes that will be delivered by Barratt Homes;
2. **Meridian Water, Enfield** — Similar design concept and also with Barratt Homes, the scheme will deliver 1,000 new homes on land adjacent to 500,000 sqft of new last mile logistics facilities.

Vertical solutions are relatively commonplace in East-Asian markets and are being explored in the U.S., the U.K., and Japan

Vertical Solutions

Increased robotics and automation lead to different requirements for daylight and height in facilities. Vertical logistics facilities have become relatively commonplace in East Asian markets, where the lack of appropriate industrial land makes such facilities a viable option.

Figure 157. Asia Has Pioneered the Multi-Story Logistics Facility

Location	Asset	Floors
Kowloon Bay	Sunshine Kowloon Bay Cargo Centre	10
Tsuen Wan	Global Gateway	25
Tsuen Wan	Kerry Cargo Centre	20
Kwai Chung	ATL Logistics Centre	13
Kwai Chung	HK International Distribution Centre	14
Kwai Chung	Modern Terminal Building	12
Kwai Chung	NWS Kwai Chung Logistics Centre	5
Tung Chung	Airport Freight Forwarding Centre	3

Source: Citi Research

Similar schemes are starting to appear in both the U.S. and the U.K., although both of these markets are still in their infancy.

Currently the only purpose-built, multi-story logistics facility in the U.K. is X2, a 150,000 square foot facility in Heathrow, developed by Segro in [2011]. While an innovative concept, X2 was expensive to build and as a result the asking rents were above market level on opening, and the facility took a long time to let up. Ultimately Segro had to drop the rents to lease up the asset and highlights (1) the potential risk of speculative development; and (2) the importance of delivering what the market requires despite the ground-breaking nature of the concept.

Prologis recently kicked off the first multi-story project in the U.S. with a new development in Seattle which will total 580k square feet and is expected to deliver in 2018. The building will include three stories once completed. Multi-story development will likely be used in extremely land-constrained markets where rents can overcome the increased development costs of this type of facility.

In Japan, the last few years has seen a sharp increase in new construction of large warehouses/distribution centers. According to Jones Lang Lasalle, in 2016 nearly 1.1 million square meters of large-sized distribution centers (>10,000 sq.m.) were opened in Greater Tokyo, an increase of 7% year-over-year. In 2017, growth is forecast to be ~3%. The main driver of this demand growth is the e-Commerce sector which required approximately 500,000 square meters of new space last year.

As an example of what is being built, GLP J-REIT plans to open a six building distribution complex covering 650,000 square meters by 2022 in Sagamihara, to the west of Tokyo, with a total investment of ~\$1.1 billion. The flip side of this expansion is growing vacancy rates in smaller, older distribution centers not located close to highway inter-sections.

Underground Logistics

Underground networks could be an innovative approach to addressing land shortages in urban cities

Formal Investments has submitted a planning application to Hounslow Council for the excavation and development of a 2 million square-foot underground logistics facility, which would be similar in concept to the National Car Parks (NCP) car park underneath Hyde Park in London. Under the proposals submitted, the underground network would comprise a 9 meter elevation and would be split into multiple 80,000 square foot units.

The proposals demonstrate another innovative approach to addressing land shortages in urban cities. However, there are still a number of concerns regarding not least the expected construction costs, which are expected to be significant, and the viability of the schemes depends in large part on the value that will be achieved in selling the gravel extracted from the site during the excavation of the site.

Further issues regarding how a subterranean shed could incorporate sufficient loading docks and vehicular access to support a high-frequency logistics operator remain unanswered.

The success of the SubTropolis scheme in Kansas, a 55 million square-foot underground storage facility in legacy mine shafts, provides some support for the scheme should the design be able to provide sufficient cubic space and head clearance to be deemed viable.

Shared/Flexible Warehousing (AirBnB)

Small and medium-sized enterprises (SME's) trying to compete with major players in the modern, global logistics arms race (Amazon, John Lewis, ASOS.com) often face difficulty in securing adequate warehousing on a cost-effective basis. As a result, several new companies aimed at providing on-demand warehousing have emerged in recent years.

These companies aim to emulate the success of the 'Fulfillment by Amazon' concept by leveraging cloud computing systems to provide a quick and flexible storage and distribution service, matching demand with empty space in existing warehouses. These platforms are driven by the Software as a Service ("SaaS") concept enabling software access via Internet connections rather than wired, localized installation.

The concepts seek to leverage the fundamentals of social networks and the sharing economy to provide on-demand flexibility and capacity to meet seasonal demand.

Cloud computing systems providing quick and flexible storage and distribution systems can match demand with empty space in existing warehouses

Flexe has established a network of warehouses in the U.S. with greater geographic presence than Amazon, without investing in physical real estate

One of the pioneers of this new concept is a U.S. company called Flexe, which has been described recently as the equivalent of AirBnB for the warehousing industry. The company has created an online marketplace of spare storage space across 550 warehouses in the U.S., meaning that in five years the group has established a network with greater geographic presence than Amazon, without investing anything in physical real estate. Furthermore, the business is gaining significant traction given it can match Amazon Prime on both service and price, while also offering customers the ability to deliver products in own-branded packing, unlike Amazon.

Other businesses offering cloud-based on-demand storage and logistics include:

1. **Shipwire:** A Global SaaS platform offering scalable on-demand and custom fulfillment solutions through leveraging parent Ingram Micro's network of 154 distribution centers throughout 45 countries worldwide.
2. **Stowga:** A U.K. based business-to-business (B2B) platform offering flexible, on-demand storage and logistics for industrial scale palletized goods. It provides coverage across 4,000 warehouses, predominately operated by professional third-party logistic firms (3PL's), warehousing specialists, manufacturers and/or haulage firms.
3. **Cargomatic:** Seamlessly connects both shippers and carriers through proprietary online and mobile applications providing real-time connectivity to solve short-term warehousing and delivery capacity issues.

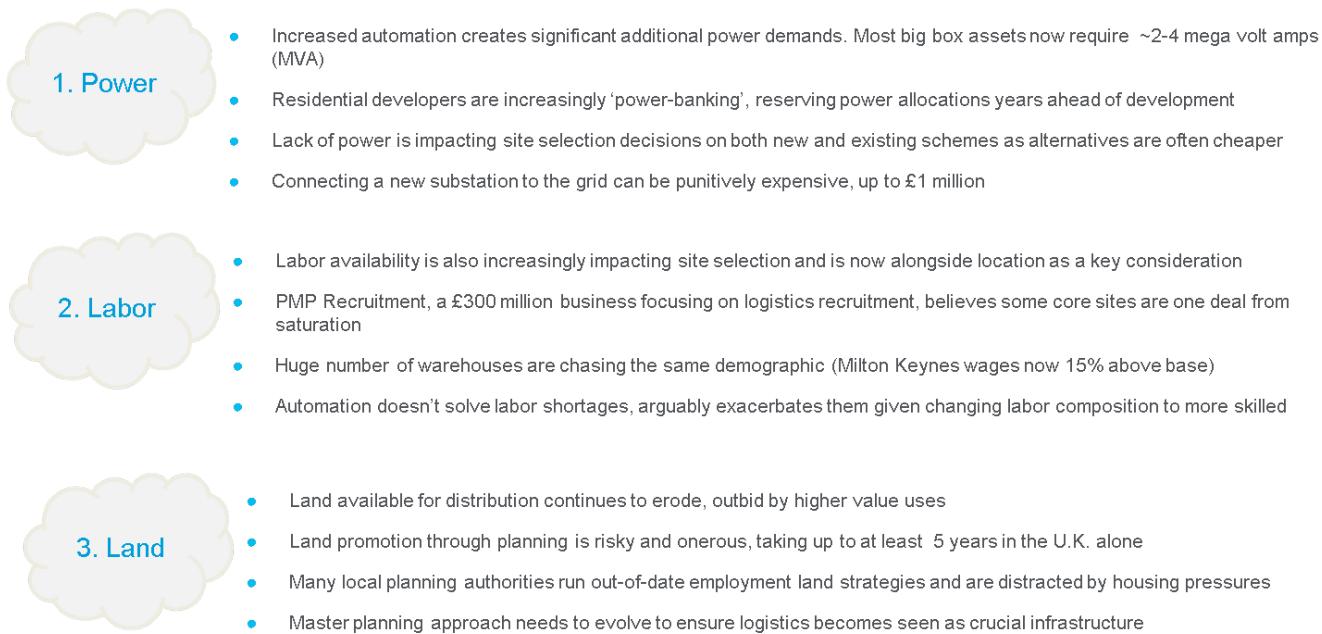
4. **Roadie:** Similar to the on-demand delivery service offered by UberRUSH, Roadie matches customers to drivers who offer door-to-door delivery for items utilizing space in their vehicles on journeys they are already undertaking. For example commuters willing to collect and deliver goods on their way home.

Headwinds/Risks/Clouds on the Horizon

As we have discussed, increased automation and the application of technology has caused seismic changes in the real estate market, not least through the apparent shift of the retail channel from traditional brick-and-mortar offering to omni-channel. Industrial real estate has been the major beneficiary of this change, one which by most accounts is set to continue to disrupt how consumers buy and receive goods.

However, despite the significant secular tailwinds, there are a number of clouds developing on the horizon, which boil down to the fundamental question of resource allocation. The three key areas where scarcity is starting to impact real estate site selection are set out in Figure 158 below.

Figure 158. Tailwinds Blowing Clouds onto the Horizon

- 
- 1. Power**
 - Increased automation creates significant additional power demands. Most big box assets now require ~2-4 mega volt amps (MVA)
 - Residential developers are increasingly 'power-banking', reserving power allocations years ahead of development
 - Lack of power is impacting site selection decisions on both new and existing schemes as alternatives are often cheaper
 - Connecting a new substation to the grid can be punitively expensive, up to £1 million
 - 2. Labor**
 - Labor availability is also increasingly impacting site selection and is now alongside location as a key consideration
 - PMP Recruitment, a £300 million business focusing on logistics recruitment, believes some core sites are one deal from saturation
 - Huge number of warehouses are chasing the same demographic (Milton Keynes wages now 15% above base)
 - Automation doesn't solve labor shortages, arguably exacerbates them given changing labor composition to more skilled
 - 3. Land**
 - Land available for distribution continues to erode, outbid by higher value uses
 - Land promotion through planning is risky and onerous, taking up to at least 5 years in the U.K. alone
 - Many local planning authorities run out-of-date employment land strategies and are distracted by housing pressures
 - Master planning approach needs to evolve to ensure logistics becomes seen as crucial infrastructure

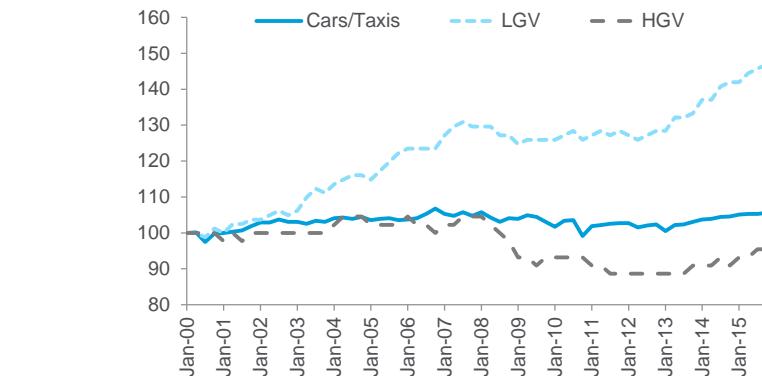
Source: CBRE, Citi Research

Finally, while there are real estate winners from the deepening use of technology and automation, there is also likely to be increasing quantums of losers, primarily secondary and tertiary locations and assets which fail to adapt to modern patterns of consumption. As a result the levels of obsolescence within real estate is likely to increase. The primary example of this trend currently is the growing swathes of empty/ghost retail space in the U.S.

The Impact on Traffic Congestion

In 2000, 11% of road vehicle miles in the U.K. were made by light goods vehicles (LGVs), up to 15% by end of 2015. LGV road vehicle miles were 8.1 billion in 2000 and rose up to 11.9 billion in 2015, a compound annual growth rate of 2.6%. While this may sound small, since 2008 LGV miles have grown at a compound annual growth rate of 1.8% while miles by heavy goods vehicles (HGV) have declined at a 1.8% rate. For context, U.K. GDP has been broadly flat since 2008.

Figure 159. Road Traffic (Vehicle Miles) in the U.K. by Vehicle Type (Q1 2000 = 100)



Source: Citi Research, Department for Transport

Impact of Real-Estate in Japan

Increases in size, functionality of logistics facilities

Before the emergence of leading-edge logistics facilities in Japan, warehouses only served as somewhere to store products before shipment. More recently, a large number of big, highly-functional, modern logistics facilities have been built to meet the need for advanced logistics systems, so the environment for logistics facilities has changed significantly.

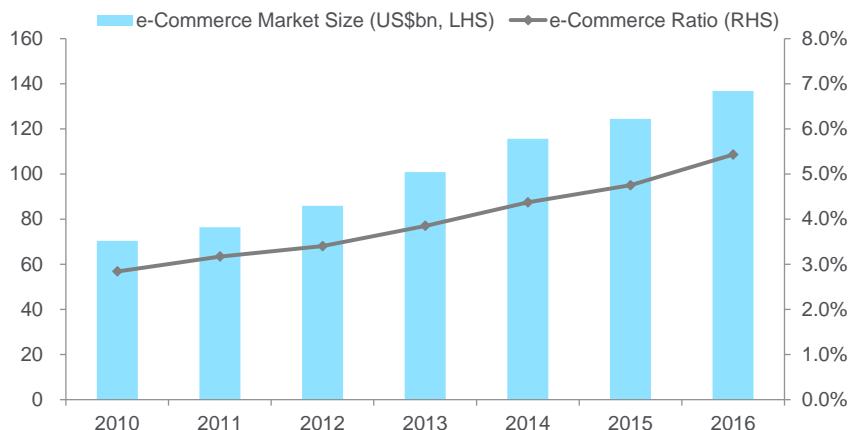
Growth in e-Commerce market

Growth in Japanese personal consumption is weak, because of the decline in the population and uncertainties regarding the macroeconomic outlook, but the e-Commerce market continues to grow. Indeed, the e-Commerce market expanded from just ¥6.1 trillion (\$56 billion) in 2008 to ¥15.1 trillion in 2016 (\$138 billion), while the weighting of e-Commerce within the overall retail market rose from 2.8% in 2010 to 5.4% in 2016. Drivers include an increased diversity of products sold via the Internet and growth in the number of sellers, the growing market uptake of smartphones, and the rationalization of home delivery thanks to advancements in logistics facilities.

Increasing market uptake of smartphones one driver of market growth

The increasing market uptake of smartphones has contributed considerably to growth in the e-Commerce market. The amount of purchases made via smartphones increase by around ¥0.6 trillion (\$5 billion) in one year, from some ¥2.0 trillion (\$18 billion) in 2015 to about ¥2.6 trillion in 2016 (\$24 billion), while the proportion of Internet purchases made via smartphones rose from 27.4% to 31.9%. While the Japanese population is aging, the market penetration rate of smartphones for people in their 20s and 30s is now above 90%, although it remains less than 40% for people aged 60 and older. We think market uptake of smartphones will increase over time for a broad range of age groups, driving increasing market penetration of Internet retailing and further growth in the Japanese e-Commerce market. Nomura Research Institute forecasts growth in the e-Commerce market to ¥25.1 trillion (\$230 billion) in 2020.

Figure 160. Business-to-Consumer e-Commerce Market Size and e-Commerce Ratio



Source: METI, Citi Research

Scarcity of advanced logistics facilities.

While e-Commerce retailers do not need shop floor displays, they do need to deliver goods to consumers in a timely fashion. Given also the diversification of customer needs, there is increasing demand for modern, highly-functional logistics facilities capable of frequent, small-lot deliveries. The number of items handled by parcel delivery companies grew by roughly 1.5x between 2000 and 2014. Demand for leading-edge logistics facilities continues to grow as the e-Commerce market expands, but the Japanese stock of such facilities is very small. The total Japanese stock of logistics facilities was 504 million square meters at end-March 2016. Of this, only 3.9%, or 19.9 million square meters was leading edge facilities (facilities with advanced designs and at least 10,000m² of floor space).

Supply-demand tight, but . . .

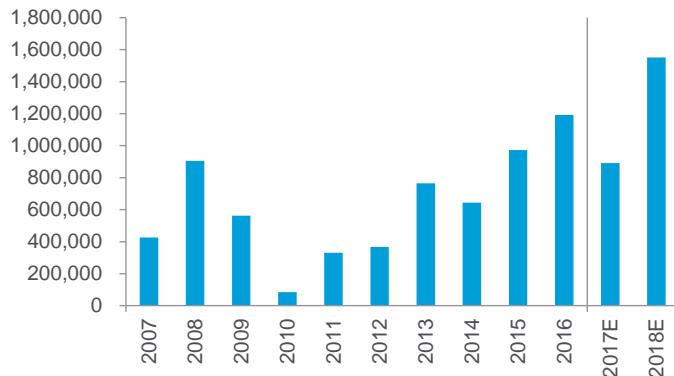
Supply-demand for logistics facilities has been very tight in the Tokyo and Kinki regions since the 2011 east Japan earthquake, and the realization of latent demand has quickly absorbed new supply so vacancy rates have remained consistently low. Since their listing in 2012, the big logistics REITs – GLP J-REIT and Nippon Prologis REIT – have continued to raise rents on existing properties, benefiting from the favorable supply-demand environment.

Numerous new entrants

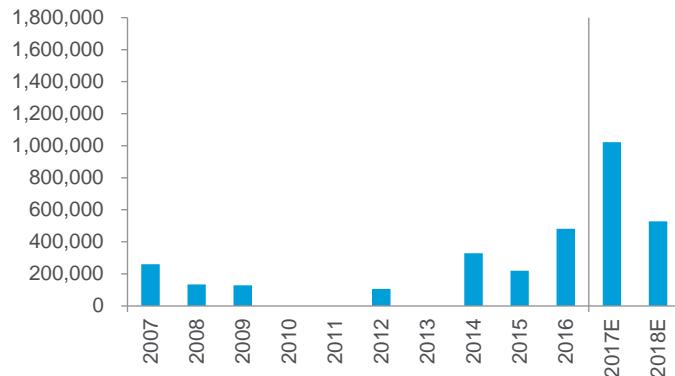
There has been an increase in the number of logistics property players as they attempt to meet growing demand and tap into investment opportunities in a rare growth market, so the supply of advanced logistics facilities continues to expand. Big hybrid developers such as Mitsui Fudosan have accelerated the development of large logistics facilities over recent years, making full entrance into the market with the listing of subsidiary logistics REITs. LaSalle Logiport REIT and Mitsui Fudosan Logistics Park are logistics REITs that have listed since 2016, and the media reports plans to list logistics REITs by Mitsubishi Estate and CRE Inc.

New supply at all-time high

As a result of strong investment in logistics facilities, the new supply of large, multi-tenant logistics facilities in the Tokyo region reached an all-time high of 360,000 tsubo (approximately 1.2 million square meters) in 2016, and while this is expected to slow to 270,000 tsubo (around 900,000 square meters) in 2017, a new all-time high of 470,000 tsubo (about 1.6 million square meters) is planned for 2018. New supply of 146,000 tsubo (approximately 482,000 square meters) in the Kinki region was an all-time high but a much larger 310,000 tsubo (about 1.0 million square meters) is planned for 2017 before a decline to 160,000 tsubo (around 530,000 square meters) in 2018.

Figure 161. New Large Multi-Tenant Supply in Greater Tokyo (m²)

Source: CBRE, Citi Research

Figure 162. New Large Multi-Tenant Supply in Greater Osaka (m²)

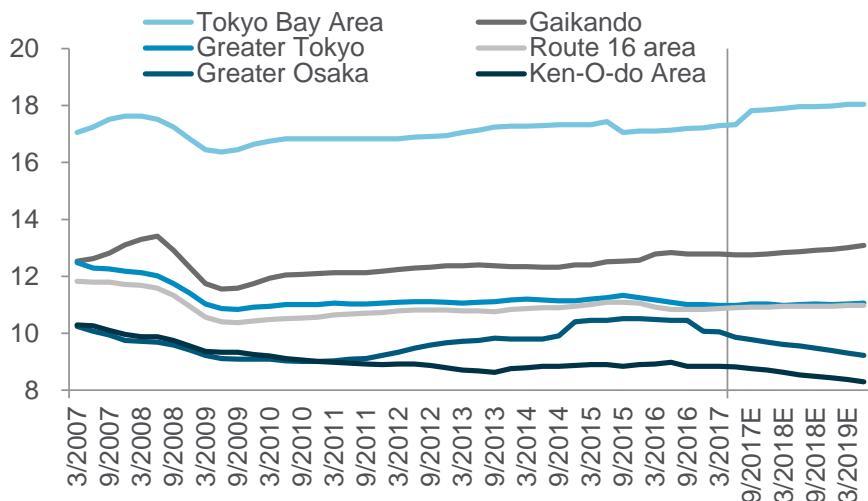
Source: CBRE, Citi Research

Polarization in logistics facility fundamentals

While demand remains strong, the rapid growth in supply has caused a deterioration in the leasing environment in some areas, so vacancy rates have risen and the rents offered declined. It is mainly areas in which new supply is concentrated that have struggled, with it taking a longer time to complete leasing particularly in areas with poor transport where it is difficult to hire workers. The leasing environment remains favorable in the Tokyo Bay area, where there has been little supply, and inland Osaka areas, where there was almost no stock, so there has been a polarization in logistics facility fundamentals.

Future supply is expected to remain high in the Tokyo and Kinki regions, so this polarization is likely to continue for some time. If it does, it should be relatively positive for pioneering developers such as GLP J-REIT, which have large holdings of favorably located existing properties on which current rents are below market levels. But even given the expected ongoing growth in logistics real estate, the later entrants may not generate the profits they expect. The prices of construction materials and labor costs have risen markedly in recent years, due to reconstruction following the east Japan earthquake and ahead of the Tokyo Olympics, so the cost of building new properties has risen. Developers must be able to pass this increase on by raising rents, but the continuing large amounts of supply are putting downward pressure on rents.

Figure 163. Real Rents for Large Multi-Tenant Logistics Facilities (US\$ per square meter)



Source: CBRE, Citi Research.

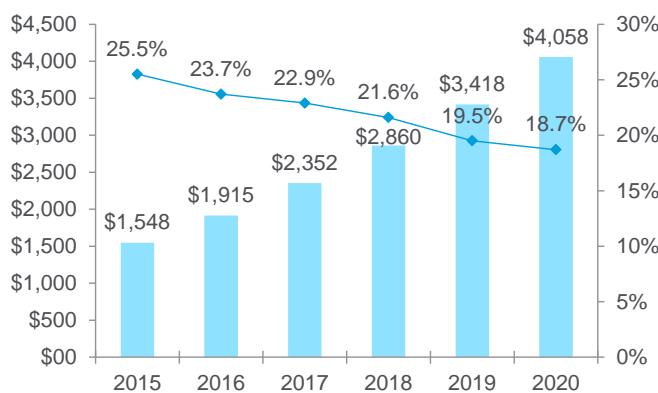
Delivering E-Commerce

Market Developments

e-Commerce is expected to be particularly strong in China, rising to 47% of all sales

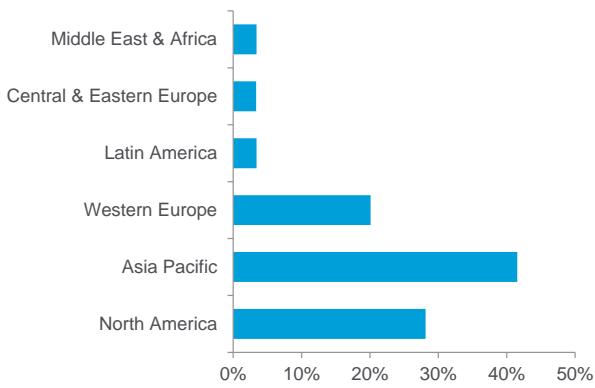
eMarketer expects global retail e-Commerce sales to grow 23.7% in 2016 to reach \$1.9 billion or 8.7% of total global retail spending. eMarketer expects Asia-Pacific to remain the world's largest retail e-Commerce market with sales expected to top \$1 trillion in 2016 and more than double to \$2.7 trillion by 2020 as illustrated in Figure 164. Around 90% of retail e-Commerce in Asia-Pacific will come from China, where sales are expected to reach \$900 billion in 2016 — 47% of all such sales worldwide. Elsewhere in Asia-Pacific e-Commerce represents a fraction of total retail sales that eMarketer attributes to underdeveloped digital payments infrastructure and a weak logistics framework unsuitable for high volumes of e-Commerce orders. DHL cites research predicting e-Commerce sales growth of 16% per year to 2020, with a total market of between \$4 trillion and \$4.5 trillion, and cross-border rising 25% per year to 2020 and becoming 22% of all e-Commerce, representing a market of nearly \$1 trillion. Deutsche Post DHL expect relevant parcel and express markets to grow from €199 billion in 2015 to €268 billion in 2020, with an EBIT pool of €19 billion.

Figure 164. Global e-Commerce (US\$bn)



Source: eMarketer

Figure 165. e-Commerce Share per Region (2016)



Source: eMarketer

Cross-border B2C e-Commerce is expected to more than double over the next five years

Separately Forrester Research expects cross-border business-to-consumer (B2C) e-Commerce to more than double over the next five years to reach \$424 billion by 2021. China will drive cross-border growth, and its share of the online cross-border market is expected to grow from 27% in 2015 to 40% in 2021. Cross-border sales will take an increasing share of e-commerce, rising from 12% in 2015 to 15% in 2021. Boston Consulting Group (BCG) echoed Forrester's sentiment over cross-border e-Commerce, highlighting that even in affluent countries <20% of non-food and <5% of food purchases are met by e-retailers and that e-Commerce volumes are forecasted to triple by 2021. BCG believes up to 70% of all retail spending would migrate online if all barriers to e-Commerce were removed in every category. BCG asks whether the strong competitive position of incumbent parcel companies would be eroded with dramatic changes in volume. BCG notes: (1) higher drop density would disproportionately improve delivery economics for smaller rivals; (2) higher drop density would encourage the spread of disrupter's in-house delivery to medium and small cities; and (3) widespread grocery delivery via dedicated networks could deliver non-food parcels at little incremental cost.

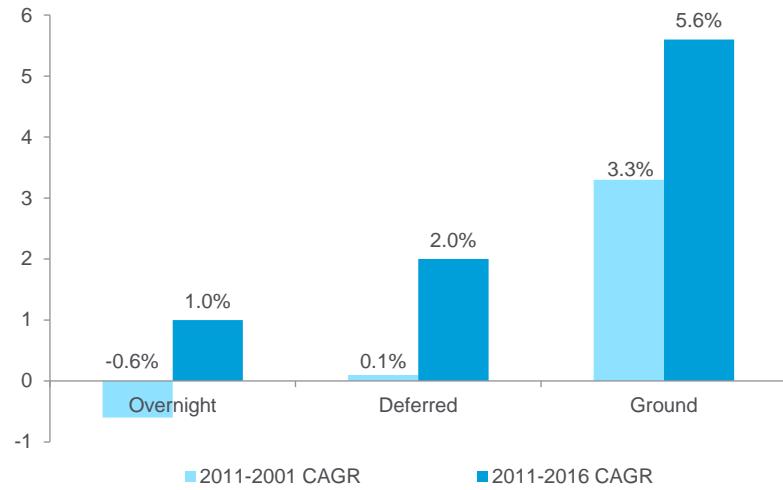
E-Commerce Has Increased Delivery Speeds and Asset Intensity

Through its Prime service offerings, Amazon has molded the consumer psyche to expect 'free' two-day shipping on B2C residential deliveries while ignoring the upfront annual sunk costs of its membership fees. Faced with the competitive threat from Amazon's promised service levels, traditional brick-and-mortar retailers — who have historically lagged Amazon in developing e-Commerce networks — are being forced to solve the problem of meeting these shifted consumer expectations on delivery timing and costs. Larger retailers like Walmart and Target possess a footprint large enough to build or acquire logistics networks to insource their transportation management needs (similar to Amazon), while simultaneously innovating to leverage their existing supply chains for physical stores. Outside of these ultra-large entities, retailers rely on a combination of the integrated package carriers (FedEx, UPS, DP-DHL) and in North America, the United States Postal Service (also heavily utilized by Amazon).

Growth rates of faster service level products (i.e., Overnight & Deferred/2-Day) are faster than slower ones (i.e., Ground)

The result has been an acceleration of overall business-to-consumer delivery speeds through the airfreight/parcel networks. This can be seen in the relative growth rates of faster service level products (i.e., Overnight and Deferred/2-Day) versus slower ones (i.e., Ground). To be clear, the majority of e-Commerce packages have historically been driven through Ground networks, and this continues to be the case. Since 2001, total U.S. package volumes for FedEx and UPS combined have grown at a 2.3% compound annual growth rate, driven by 4% annualized Ground volume growth. Ground traditionally provides 3+ day delivery times to most of the U.S. and handles the largest portion of e-Commerce volumes. However, Amazon Prime memberships grew eight-fold between 2011 and 2016, with current estimates putting total memberships at ~80 million. Splitting this period up into pre- and post-2011 growth rates shows an interesting dynamic in growth rates for the parcel carriers' service levels that demonstrate the shift towards greater speed in required e-Commerce deliveries.

Figure 166. Amazon Prime's Post-2011 Boom Drove Higher Growth For Faster Parcel Products

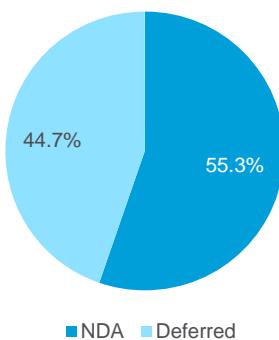


Source: Company Reports and Citi Research Estimates

Between 2001 and 2011 Overnight volumes declined by 60 basis points on an annualized basis while Deferred grew nominally at 10 basis points per year. Ground volumes grew at 3.3% on an annualized basis, which also captures the multi-year ramp up of FedEx's Ground segment (former RPS). However, Overnight and Deferred growth rates accelerated post-2011, most notably in Deferred, which grew by 2% annually from 2011 through 2016, or at a ~200 basis point faster clip than in the preceding 10 years. This growth in 2-Day service levels represents the overflow of 15% annualized e-Commerce volume growth into the parcel carriers' Express/Time-Definite networks, as network capacity has strained to handle increased demand.

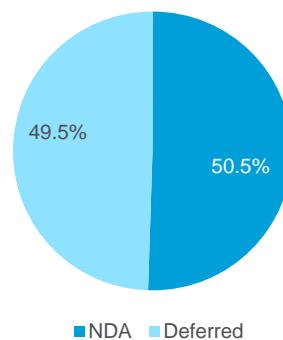
The shift is also evidenced in UPS' Air Products mix, which has shifted by 480 basis points toward Deferred products since 2011, or from 44.7% of total Air volumes to 49.5%. UPS Deferred offering is more levered to e-Commerce than its Next Day Air ("NDA") product. NDA's contraction from 55.3% of mix to 50.5% over the same time period correlates to slowing business-to-business growth, which has decelerated meaningfully in the past 3 years.

Figure 167. UPS Air Products Mix: 2011



Source: Company Reports, Citi Research

Figure 168. UPS Air Products Mix: 2016



Source: Company Reports, Citi Research

Increased Aircraft Purchases and Conversions

Carriers are refleetng their aircraft to alleviate network strain

One of the ways in which the carriers are responding to network strain is through a combination of increasing asset intensity and refleetng its aircraft. Earlier this year, UPS announced a multi-year increase in network investments that includes 14 new 747-8F aircraft and the conversion of three 767-300 passenger aircraft to cargo planes by Boeing, totaling over \$5 billion in capital expenditures. FedEx has been more proactive in fleet replacement over the past four years (as part of its Express profit improvement plan ended in 2016), but also expects to take delivery of 36 planes over the next two years, of which 21 will be replacement aircraft, in addition to major Ground network investments over the next 12 months.

Carriers and Retailers Are Innovating to Create Delivery Density

The long-standing structural problem with residential delivery is the lack of package density per stop. That is, at ~1.2 packages per stop, business-to-consumer residential deliveries erode the economies of scale present in business-to-business, absent substantial pricing increases.

Figure 169. Amazon Locker Creates Density



Source: Wikimedia Commons (licensed for reuse)

However, as consumers expect 'free' delivery, increasing pricing to offset decremental margin impact has been problematic for the industry as a whole. One of the ways in which this is being addressed in North America is the increased roll-out of consolidation points, such as UPS' 26,000+ Access Point locations and FedEx's Ship & Get stations (including roll-out to 8,000 Walgreen's stores by the fall of 2018). Amazon has installed lockers nationwide as well, notably partnering with the convenience store chain 7-Eleven. In Europe, these sorts of consolidation and access points have existed for years (e.g. DHL's inPost lockers).

With its greater exposure to e-Commerce and larger Ground operation, UPS is particularly focused on innovations that can generate density. At current levels, an improvement of one-tenth of a package per stop in delivery density increases annual earnings before interest and taxes (EBIT) by \$200 million. In addition to leveraging its network of Access Points, UPS recently announced the implementation of surcharges for residential delivery for this year's high volume holiday/peak period, including an ~8% increase on Deferred products versus reported levels in the fourth quarter of 2016.

Pallet Technology

New Tracking Technology Coming to Pallets/Bins

Currently the real-time visibility in the supply chain is at the vehicle level (truck/delivery van) via GPS tracking technology. GPS technology is not expensive relative to the asset they are attached to, but the cost of the unit and the cellular connection makes these devices less economic and practical in smaller parts of the supply chain. The lack of economics is a function of their unit price and connection cost, and lack of practical application is their short battery life.

These constraints are changing as Internet-of-Things (IoT) networks are being rolled, and the cost of physical units and connection costs are being reduced. The batteries of IoT connected devices are also predicted to last past 10 years, removing a key practical constraint of GPS technologies.

What Are the Key Benefits of Tracking Pallets/Bins

Customer visibility and adjusted delivery times, greater location information for shippers and receivers, and real-time information on stock levels are all benefits of tracking pallets/bins

As seen in Figure 29, speed of delivery remains a problem when buying over the Internet. A late delivery is a delivery failure, but as smaller parts of the supply chain are proactively tracked (unlike RFID which is a passive technology) there is greater ability for customers to have visibility into delays and adjusted delivery times.

In addition to the greater location information available to shippers and receivers, IoT devices will be able to report heat and vibration while moving between manufacturer and retailer's distribution center, or fulfillment center. This allows more specialized products (pharmaceuticals, wine, fragile items) to be shipped with greater confidence of the journey, in addition to the location benefits for just-in-time inventory management.

Within a retailers/distributors own supply chain, we see the potential for IoT devices to supply real-time information on stock levels by reporting the weight of products on pallets or within individual bins, further reducing the risk of stock outs.

In addition, the better managing of customer expectations — providing real-time location information to customers, relative to the destination — is expected to provide greater engagement with retailers that adopt such technology.

How Far Away Is the IoT from Impacting Supply Chains?

IoT is beginning to impact supply chains

In late October 2016, AT&T enabled a site in San Francisco that provides a Low-Power Wide-Area network for machines to connect to under the umbrella of IoT. Other sites will be progressively rolled out throughout North America.

This rollout is an upgrade to existing sites and will be scheduled across 2017, involving an upgrade to software of the different vendor architectures; it does not require the replacement of existing infrastructure.

Pallet Provider RM2 Trialing IoT with AT&T

RM2 Group is already trialing IoT enabled pallets within North America with AT&T. We expect the initial capability of the devices will be to report the daily location of each pallet, which is then linked to a manufacturer's load.

The technology being adopted by RM2 works more efficiently on a local traffic manager (LTM) network, but is able to use the long-term evolution (LTE) network if unable to find an LTM network. While this will have some impact on the battery life, it allows for the same visibility of asset-tracking ahead of the full LTM rollout.

The other consideration will be the length of time assets spend in Canada and South America – as AT&T's network extends into Mexico and Puerto Rico, but will rely on roaming agreements for other countries that could take longer to upgrade to LTM. The impact of this will again be on battery life rather than a lack of visibility.

It is expected the units that are being installed in RM2 pallets will have a battery life of over 10 years. With the ongoing evolution of battery technology, there is potential to increase battery life toward 12–15 years, thereby providing more than enough coverage for the expected useful life of the RM2 pallet.

Background on Low-Power Wide-Area Networks (LPWA)

LPWA networks are expected to be increasingly used as LPWA technologies provide a better alternative to others for communication to pallets

LPWA networks are expected to be increasingly used for the communication between many civic, industrial, and other IoT applications given the advantages over other wireless technologies like Wi-Fi, Bluetooth etc. At present this technology is still in early stages with numerous protocols like LoRa, SigFox, LTE-M, and many others are being developed.

While it remains to be seen which one of these technologies becomes the widely accepted industry standard, the number of devices connected to the LPWA networks are expected to see a significant increase over the coming years.

The main reasons we see LPWA technologies providing a better alternative compared to others for communication to pallets are as follows.

1. **Low cost:** It is expected hardware costs will be much lower at \$5–\$10, and the costs would decrease in price as large-scale production begins. The connectivity or the data costs are also expected to be much lower than existing services. But it remains unclear what the connectivity costs would be on a per month basis. The costs could be \$1–\$2 per year.
2. **Low energy consumptions:** Given the consumption of data is expected to be very low with no frequent communication requirement, the battery life is expected to last for 10 or more years.
3. **Extended range:** The coverage is expected to be 7x better than the traditional cellular networks, and it also includes improved connectivity to locations like parking buildings and basements.
4. **Scalability:** Because the licensed LPWA operates on the existing spectrum from the LTE network managed by mobile operators, it can be scaled relatively quickly, as simply by upgrading software to the existing LTE network.
5. **Security:** is expected to be at the levels similar to LTE networks.

Consequently, LPWA network can be thought of as the intersection of low power nodes communicating over long distances.

The End of Retail Employment? Automation and the Future of Jobs

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“Imagine this scene from the future: You walk into a store and are greeted by name, by a computer with facial recognition that directs you to the items you need. You peruse a small area — no chance of getting lost or wasting time searching for things — because the store stocks only sample items. You wave your phone in front of anything you want to buy, then walk out. In the back, robots retrieve your items from a warehouse and deliver them to your home via driverless car or drone.”²

The above imagined future, described in *The New York Times*, is not far away. The Amazon Go stores have no cashiers or checkout personnel. Customers simply scan their phones when they enter while improved sensors equipped with computer vision keep track of the items they put in their carts. Needless to say, because Amazon Go is not yet open to the public, its employment impacts are still to be seen. What is clear is that such developments might constitute a watershed to labor markets in the future. In the past, automation has been largely confined to routine rule-based activities that are easy to specify in computer code. Today, the potential scope of automation extends far beyond routine factory and clerical work, as the Citi/Oxford Martin School GPS *Technology at Work* series has documented.

Will the human worker follow the horse
down the road to complete obsolescence?

In the light of rapid advances in artificial intelligence, 3D printing, mobile robotics, Internet-of-Things, self-service technology, etc., it has frequently been suggested that the human worker will follow the horse down the road to complete obsolescence. To be sure, during the early days of the Second Industrial Revolution, it seemed unlikely that even horses would be displaced. Yet some did foresee such a development. In 1895, a new journal arrived in New York City entitled *The Horseless Age*. It was created by its editors in response to the invention of the automobile. All the same, even though horse travel was slow, uncomfortable and expensive, a horseless age looked unlikely to most contemporaries. Indeed, just four automobiles were produced in the United States that year; the industry was in an embryonic state. Even in Germany, where the modern automobile first emerged, Kaiser Wilhelm II is said to have remarked “I believe in the horse. Automobiles are a passing phenomenon.” At the time, the obstacles to the widespread adoption of the automobile were still plentiful. Production costs were high, a comprehensive road system was lacking, and fuel was expensive. The displacement of the horse did of course not happen overnight, but as the bottlenecks to automobile adoption were overcome the horse population gradually declined. In the 1920s (some three decades after the first issue of *The Horseless Age*) there were still some 25 million horses and mules in America; by the 1960s the population had declined to 3 million.

The twentieth century witnessed the mechanization of just about everything. But even though no industry was left unaffected by the force of technology, a jobless age did not materialize despite such fears. In 1930, John Maynard Keynes famously argued that the pace of automation was proceeding more rapidly than “the problem of labor absorption” could be dealt with. Our means of automating jobs, he argued, was outrunning the pace at which new jobs were being created, leading to widespread technological unemployment. That Keynes’ prediction is yet to come true has often been remarked. Nonetheless, the fact that the horseless age was not

² Cain Miller (2017 June 17). Amazon’s Move Signals End of Line for Many Cashiers. *NY Times*. Retrieved from: <https://www.nytimes.com/2017/06/17/upshot/amazons-move-signals-end-of-line-for-many-cashiers.html>

accompanied by a jobless age does not mean that Keynes overestimated the potential scope of automation. In fact, Keynes' assessment of the susceptibility of existing jobs to automation was largely accurate. Few of the jobs that existed in 1930 have not been automated away. Keynes accurately suggested that the technologies that "so far chiefly affected industry may soon be attacking agriculture." In absolute terms, agricultural employment peaked around 1910; by 1930 the sector had lost 1.2 million farming jobs since its peak; and by 1960 another 4.5 million jobs had disappeared. According to estimates by the U.S. Department for Agriculture, autos and trucks saved some 1.5 billion man-hours between 1920 and 1944. But the greatest saving came from the tractor, which by 1960 had saved 3.4 billion man-hours.

The prediction by Keynes in 1930 that agriculture, mining, and manufacturing could be performed with a quarter of workers was not far-fetched. Keynes did not overestimate the potential scope of automation. He underestimated the demand for new jobs in other sectors

Keynes' prediction that "we may be able to perform all the operations of agriculture, mining, and manufacture with a quarter of the human effort to which we have been accustomed" was by no means far-fetched. On the contrary, it has already materialized. Today, some 1.4% of Americans still work in agriculture, 0.6% remains employed in mining, and 8.1% work in manufacturing. The reason that we never saw the widespread technological unemployment that Keynes predicted was not because he overestimated our technological capabilities. It was because he underestimated the demand for new jobs elsewhere: Rising productivity spurred demand for activities that have little or nothing to do with advances in technology, such as fine dining, professional services, personal training, or cleaning services.

To predict the future composition of the workforce with any degree of accuracy is an almost impossible undertaking. What we do know is that the potential scope of automation has expanded rapidly and that many of today's jobs will change or disappear. In a study entitled [The Future of Employment: How Susceptible Are Jobs to Computerization?](#), Carl Benedikt Frey and Michael Osborne of the Oxford Martin School estimated that 47% of U.S. jobs are at risk of being automated as a result of advances in artificial intelligence and mobile robotics. In the light of the transitions that have taken place over the past century, from agriculture to manufacturing to services, this estimate seems highly plausible.

Many jobs in existing industries are at risk: Retail jobs could vanish, and 80% of jobs in transportation, warehousing, and logistics are susceptible to automation as a result of recent technological developments

That 47% of jobs are potentially automatable does not spell the end of jobs on the aggregate. However, it does suggest the end of many jobs in *existing* industries; the lesson of the twentieth century has been that most jobs that become automatable eventually disappear. Retail is one industry in which employment is likely to vanish. Although retail employment has not declined since the rise of e-Commerce in the 2000s, technology has shifted the composition of the retail workforce instead of rendering it redundant. Yet, the next wave of automation is likely to be different. According to [The Economist](#), "At its current pace, by July 2018 retailing will have shed three times as many jobs as Amazon is due to create."³ Looking forward, our estimates show that 80% of jobs in transportation, warehousing, and logistics are susceptible to automation, as a result of recent technological developments, and another 63% of sales occupations. Like Keynes predicted the downfall of employment in agriculture, mining, and manufacturing, our estimates suggest that retail employment is likely to decline in similar fashion.

³ The Economist (2017 May 13). The decline of established American retailing threatens jobs. Retrieved from:
<https://www.economist.com/news/briefing/21721900-love-affair-shopping-has-gone-online-decline-established-american-retailing>

Jobs that could be susceptible to automation in sales, transportation, logistics, and warehouses make up 11.2% of the U.S. workforce

Overall, the jobs that are susceptible to automation in sales, transportation, logistics, and warehouses constitute roughly 11.2% of the U.S. workforce (or 16.4 million jobs). Though this is clearly a sizable figure, our estimates do not imply a jobless age; human workers, unlike horses, still hold the comparative advantage in a number of domains, including creative work, complex social interactions, and the perception and manipulation of irregular objects, as shown by Frey and Osborne (2017). But unlike manufacturing jobs, which are highly concentrated geographically, the downfall of the retail industry will affect every city and region. Groups that have lost out to automation since the Computer Revolution are still struggling to find new and better paid jobs. Mass displacement in retail would not make it easier for low skilled workers to find solid footing in the labor market.

We next proceed to discussing why there are still so many jobs in retail, and why things are likely to change.

The Retail Industry: Why Are There Still So Many Jobs?

Technological advances in retail like bar-code scanners did not hurt employment as demand expanded in tandem with retail workers becoming more productive

Despite decades of technological advances in retail, employment has expanded. So why are there still so many jobs? The case of bar-code scanners provides instructive answers.⁴ Bar-code scanning became a reality in June 1974 at a Marsh supermarket in Ohio. At first, the installation of scanners and associated point-of-sale systems was slow, but it picked up in the early 1980s. In 1985, 29% of supermarkets in the U.S. implemented the new technology. The scanners allowed stores to speed up customer check-outs and to reduce labor costs at the cash register as well as on the store floor: Bar-code scanning reduced the average wage bill per store by around 4.5% during the first decade, and associated time savings could have reduced employment as well. Yet, bar-code scanners also enabled a number of innovations in the retailing industry, including marketing promotions, price, setting and inventory management, and creating new employment opportunities. Moreover, growing productivity in the stores allowed more stores to open, leading employment to expand: Employment in sales occupations grew by more than 35% between 1979 and 1989.

But this might not hold in the future as e-Commerce allows shopping without encountering a single retail worker

So far, it seems that little has changed in employment terms (technology is a different matter). Employment has continued to expand as some tasks have been automated. Yet there are some early signs that the future might be different. This time around it is not just some tasks that are being automated; more or less the entire retail business is being challenged. The rise of e-Commerce players like Amazon constitutes only the early beginnings of the displacement of traditional retail jobs in department stores and high street shops, allowing consumers to check out without encountering a single retail worker. Indeed while the force of automation is already being felt by retail workers, e-Commerce is still in many ways in its infancy. According to estimates by McKinsey Global Institute, total Internet-related business in 2011 accounted for some 3.4% of GDP in the 13 countries examined.⁵ In the United States, the share of online retail shopping increased from 5.1% in 2011 to 8.3% in 2016.⁶ That e-Commerce has not yet rendered the retail workforce redundant is thus no mystery.

⁴ Emek Basker (2012; 2015).

⁵ MGI (2011).

⁶ The Economist (2017 May 13). The decline of established American retailing threatens jobs. Retrieved from: <https://www.economist.com/news/briefing/21721900-love-affair-shopping-has-gone-online-decline-established-american-retailing>

Job postings for retail roles at traditional brick-and-mortar stores have declined, while e-Commerce job postings have increased

The composition of the retail workforce has shifted with implications for skill requirements: Lower-skilled workers are seeing a decline, while high-skilled employment has grown during the 2000s

The rise of e-Commerce itself has contributed to the growing demand for skills

But as automation races ahead, skills requirements in retail are likely to continue to increase, while more skilled workers will be competing for fewer jobs

Yet some of the employment effects of e-Commerce are already being seen. Over the past two years annual job postings for traditional brick-and-mortar retail roles declined — including those of retail salespersons, cashiers, and retail supervisors — according to data collected by Burning Glass. Although a causal relationship is difficult to determine, the reason was most likely the expansion of e-Commerce. Over the same period, e-Commerce job postings, including both pure online services and the online branches of traditional retailers, increased rapidly: The demand for e-Commerce skills in retailing grew by 32%, while specialized roles, like e-Commerce analysts, grew by 27%.⁷

The growth of new e-Commerce jobs shall, however, not be overstated. Although growth rates have been rapid, the number of jobs is still relatively few: a mere 3.1% of retail related job postings were in e-Commerce (28,084 relative to 910,792 in traditional retail). But the composition of the workforce is clearly shifting, with implications for skill requirements. As more supermarkets and chain stores install self-service checkouts and more consumers shop online without stopping at a cashier, the demand for low-skilled workers performing routine tasks has experienced a secular decline. As shown in Figure 170, low-skilled workers in jobs exposed to automation have already declined over the course of the 2000s. The slowdown in the implied pace of automation between 2010 and 2015 speaks to the intuition that many low-skilled jobs were already automated away during the previous decade. Meanwhile, skilled workers have fared differently. High-skilled employment grew by 2.6 percentage points per year during the 2000s, suggesting that job roles changed in favor of skilled workers.

Case-study evidence supports the general statistics. As self-service checkouts displace cashiers in some tasks, they also free up time to provide better customer service in the stores. Since the implementation of self-service checkouts, the tasks performed by cashiers have gradually shifted from “receiving payment by cash, check, credit cards, vouchers, or automatic debits” to more-complex tasks, such as “assisting customers by providing information and resolving their complaints,” as shown by survey evidence collected by the U.S. Bureau of Labor Statistics. Meanwhile, the adoption of new technologies has created entirely new tasks requiring greater skill: Cashiers are increasingly required to be able to use digital technologies, including accounting software, spreadsheets, as well as database user interface and query software.⁸ Moreover, the rise of e-Commerce itself has contributed to the growing demand for skills: Burning Glass found that while only 12% of traditional retailing job postings were looking for a candidate with a university degree, the equivalent figure for e-Commerce postings was 78%.

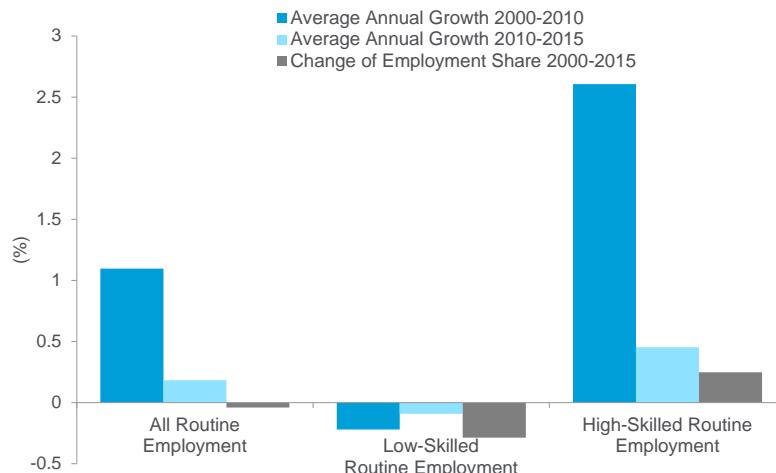
As automation races ahead, skills requirements in retail are likely to continue to increase. Yet more skilled workers are likely to be left competing for fewer jobs. Evidence from the United States is instructive. As shown in Figure 170, overall the routine employment share in the United States has already started to decline, and growth rates of high-skilled employment have dropped considerably since 2010. Thus, even skilled workers are gradually feeling the automation effect. In the past, most retail workers have moved up, not out: A sample of more than 200,000 resumes suggests that more than two-thirds of early-career retail workers advanced

⁷ Burning Glass (2017).

⁸ Beyond raising the skill requirements within existing occupations, entirely new occupations have been created as well. The rise of new occupational titles such as “creative professionals”, speak to the intuition that sales roles in stores are changing to provide additional value to consumers that chose not to shop online. Some Apple stores now even have space designed for small businesses and startups to come and get advice from app developers and other entrepreneurs.

to higher-paying occupations within five years of starting in retail.⁹ Things may, however, be changing. Estimates by *The Economist* suggest that if labor productivity improves at historical rates, retailing jobs could shrink by 12%, or 1.5 million jobs, by 2022. This is probably a low end estimate. As shown by Carl Benedikt Frey and Michael Osborne (2017), the potential scope of automation has rapidly expanded beyond routine work, suggesting that historical rates of productivity growth are likely to be a poor guide to the future.

Figure 170. Average Annual Growth in Routine Employment and the Change of Routine Employment Share in Retail Occupations, 2000–15



Notes: Figure 170 plots the average of percentage point changes in employment (more precisely, the figure plots 100 times log changes in employment, which is close to equivalent to percentage points for small changes) for the years 2000–2010 and 2010–15 for Sales occupations

Source: Authors using data from 2000 Census and 2001–15 American Community Survey, collected from IPUMS. The sample includes the working-age (16–64) civilian noninstitutionalized population. Employment is measured as full-time equivalent workers.

While the expanding scope of automation means that many warehousing and storage jobs are at risk, the main effects of automation are yet to be felt

In similar fashion, while the expanding scope of automation means that many warehousing and storage jobs are at risk, the main effects of automation are yet to be felt. As suggested by Citi's U.S. Real Estate research team, there even seems to be a labor shortage for warehouse jobs. This by no means implies that warehouses have been immune to automation. As this report has highlighted, the examples of warehouse automation are plentiful, although many are very recent, meaning that most technologies are yet to be adopted across the industry. One prominent example is the changing nature of order fulfillment and delivery: Last year Amazon filed a patent for a flying warehouse, employing drones located to airships for the delivery of goods to nearby customers. Walmart similarly introduced a system in June 2016, using drones to check if any products have been misplaced and keep track of warehouse inventories, effectively reducing the labor requirements in such tasks. Perhaps the best known example is still Amazon's Automated Guided Vehicles, which are cleverly designed to bring shelves to the picker, instead of having a picker walking to the shelf. Previously, an Amazon warehouse employee could be expected to walk between seven and fifteen miles per day.¹⁰

⁹ Burning Glass (2017).

¹⁰ Financial Times (2013).

Until developments have been made in overcoming the challenge of picking and sorting objects, there are still jobs in fulfillment centers, but these jobs are increasingly more high-skill

So why are there still so many jobs? While Amazon's robots can retrieve entire shelves and transport them, human workers are still required to pick out items from them. The dexterity and flexibility of human workers cannot yet be replaced. The robots can find and move a shelf that holds a box of shirts, for example, but they are so far not capable of removing the shirts from the box to the package to be sent to the customer. To do so, robots would have to be able to identify a wide range of objects and adjust their grips accordingly. While many robotics engineers are working on solving this task, it remains a difficult challenge. Because most order picking is still manual, and thus requires human labor, the time saved by robots in goods delivery has allowed workers to pick more goods and fulfill more orders. Developments have been made in overcoming the challenge of picking and sorting objects: RightHand robotics has built a robot that can pick items at a rate of 500 to 600 per hour — a speed on par with a worker — using machine learning and a sensorized robot hand to recognize and handle thousands of items. Still, even though robots are being used mostly to pick items from boxes, packing items to be shipped requires more complex tasks like removing hangers and nestling items into boxes. Warehouse automation has thus so far complemented the skills of workers rather than substituting for them. Hence, as the number of orders has expanded, the result has been an expansion of employment as well: The productivity gains from automation in warehouses has increased the demand for workers in picking and packing tasks, while even creating entirely new jobs in the process, such as those of supply-chain software engineers and robot technicians. Only in January of 2017, Amazon announced it would add 100,000 warehouse jobs in the United States by 2018. But a different type of warehouse worker might be required. Indeed, new warehouse positions demand more training: 53% of jobs in automated warehouses also require a university degree.

Demand for delivery services driven by e-Commerce has expanded employment in transportation and delivery

Employment in transportation and delivery has also continued to expand. Indeed the rise of e-Commerce has created more demand for delivery services. Take the example of Deliveroo, delivering food from restaurants of which many previously did not offer a delivery service. When an order is placed online, a wage-employed or self-employed driver takes on the task of delivering the food: The former unpaid task of traveling to a restaurant has now turned into a paid task done by a driver. In 2016, takeaway orders in the United Kingdom increased by 650%, and by 2017, Deliveroo employed almost 1,000 full-time employees and provided work for over 15,000 drivers across the United Kingdom.¹¹

Beyond the movement of goods, digital technology has been transforming the movement of people as well, as highlighted by the case of the Uber platform, matching drivers and passengers. According to estimates by Judd Cramer and Alan Krueger, there were up to 500,000 active Uber drivers in the United States in 2016. While the impact of Uber on total employment in taxi services has been a contested question, a 2017 study by Thor Berger, Chinchih Chen and Carl Benedikt Frey of the Oxford Martin School, entitled "[Drivers of Disruption? Estimating the Uber Effect](#)," has shed light on the question. The study shows that Uber's entry into new markets on average has led to a reduction in the earnings of incumbent taxi drivers. But it has also led to an expansion of total employment in taxi services. The average income of taxi drivers saw a decline of 10% as a result of the spread of Uber, yet the labor supply of self-employed taxi drivers on average increased by almost 50%, which is striking especially since this is a low-bound estimate. In short,

¹¹ Entirely new types of productivity growth in transportation occupations. Deliveroo plans to hire more than 300 "high-skilled and high-tech" workers to further assist the delivery service in the U.K.

even in the sector that has been most exposed to the digital economy, employment has seemingly expanded.

The Uber Effect

How have taxi drivers fared since the introduction of Uber? A 2017 study from researchers at the Oxford Martin School at the University of Oxford has provided the first empirical evidence of the impact of the 'sharing economy' on employment and wages in the most exposed industry: taxi services.

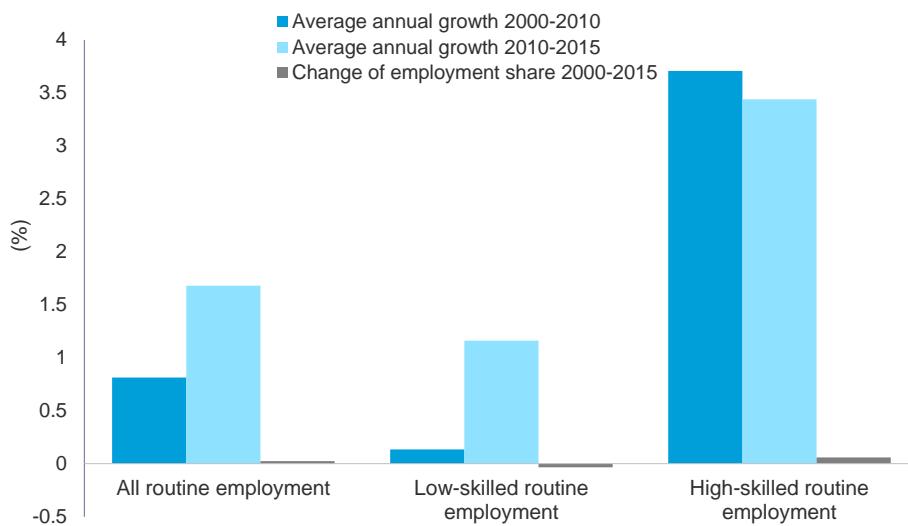
Examining the impact of the introduction of Uber across U.S. cities, authors Carl Benedikt Frey, Thor Berger, and Chinchih Chen document that Uber has positively contributed to employment in taxi services in the cities where it was introduced. The positive employment effect however came at a price: while Uber had not led to jobs being lost, it has caused a considerable reduction in the incomes of traditional taxi services.

More specifically, the authors found that on average the number of self-employed drivers in a city increased by some 50% following the adoption of the Uber platform, while reducing the wages of existing salaried drivers by 10%, relative to cities where Uber remained absent.

However, vanishing incomes of salaried drivers were in part offset by increases in hourly incomes among self-employed drivers, vindicating survey evidence suggesting that self-employed Uber drivers in America exhibit higher hourly earnings than their counterparts (Hall and Krueger, 2015). The authors argue that this reflects higher capacity utilization among Uber drivers — in terms of the share of their time spent with a passenger in the car — relative to traditional taxi drivers, as the Uber platform allows for better matching.

As documented in Figure 171, both low- and high-skilled employment in transportation, warehousing, and logistics expanded since the 2000s, even in relatively routine jobs: low-skilled employment expanded by 0.13 percentage points per year during the period between 2000 and 2010, and even picked up between 2010 and 2015, growing by 1.16 percentage points annually. High-skilled routine employment expanded even more rapidly, growing annually by 3.7 percentage points throughout the 2000s, and continued to grow by 3.4 ppts per year between 2010 and 2015. While the share of low-skilled employment dropped slightly over the investigated period, most likely due to automation, the share of high-skilled jobs expanded.

Figure 171. Average Annual Growth in Routine Employment and the Change of Routine Employment Share in Transportation/Material Moving Occupations, 2000–2015



Source: Authors using data from 2000 Census and 2001–15 American Community Survey, collected from IPUMS. The sample includes the working-age (16–64) civilian noninstitutionalized population. Employment is measured as full-time equivalent workers.

Notes: Figure 171 plots the average of percentage point changes in employment (more precisely, the figure plots 100 times log changes in employment, which is close to equivalent to percentage points for small changes) for the years 2000–2010 and 2010–15 for Transportation/Material Moving occupations

We Have Seen Nothing Yet: The Future of Retail Automation

Although concern over automation taking jobs is not new, some still believe that this time might be different

During periods when technological progress has picked up in speed, automation anxiety has often experienced a simultaneous revival. In 1952, the Nobel Prize winning economist Wassily Leontief suggested that “more and more workers will be replaced by machines. I do not see that new industries can employ everybody who wants a job.” In the 1960s, a national commission was set up in the United States to inquire whether automation would spell the end of work; and a *TIME magazine* article featuring the title “[The Automation Jobless](#)” suggested that “Today’s new industries have comparatively few jobs for the unskilled or semiskilled, just the class of workers whose jobs are being eliminated by automation.” While these predictions are yet to come true, a recent influential book entitled “The Rise of the Robots” has argued that they were just ahead of time: the next wave of automation will render the workforce redundant.

Forecasts are that the number of manufacturing jobs lost will rise as the use of industrial robots quadruples

Recent research lends some support to this view: A paper by Daron Acemoglu and Pascual Restrepo found that robots have been responsible for the loss of 670,000 lost manufacturing jobs between 1990 and 2007 and have contributed to a reduction in the employment to population ratio as well as workers’ wages. The authors argue that this number is expected to rise as the use of industrial robots is projected to quadruple. In the words of Daron Acemoglu, “even if overall employment and wages recover, there will be losers in the process, and it’s going to take a very long time for these communities to recover. The market economy is not going to create the jobs by itself for these workers who are bearing the brunt of the change.”¹²

¹² Cain Miller (2017).

The scope of automation now extends beyond routine work and the impact of automation on retail might be as profound as the displacement of manufacturing jobs

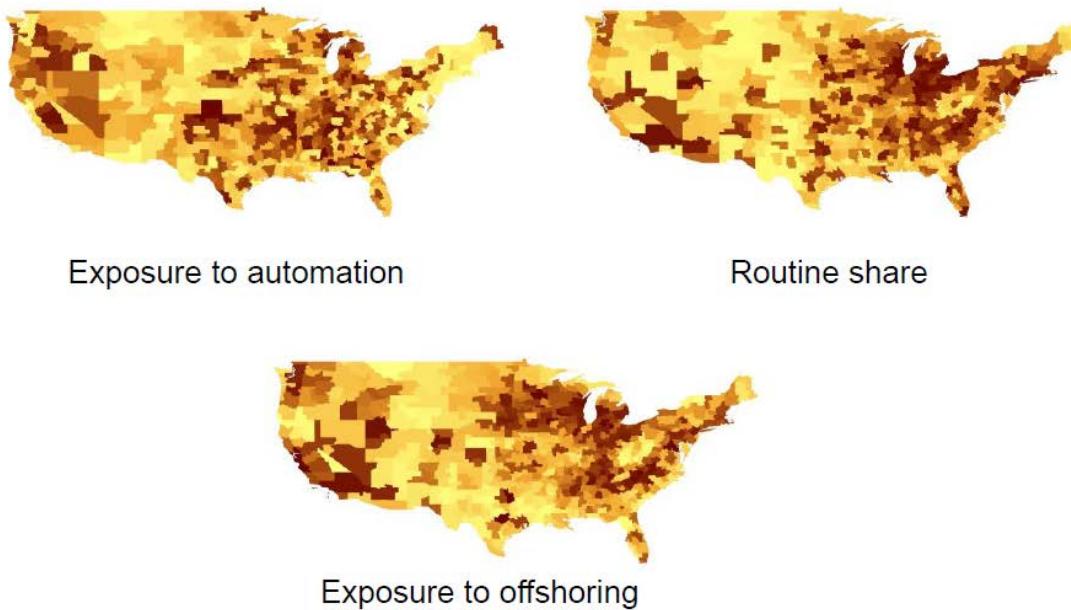
As this report has highlighted, we are now at the beginning of a “Second Machine Age.” While job automation has historically been confined to routine rule-based activities, there is plenty of evidence to suggest that the scope of automation now extends well beyond routine work. The next wave of automation technologies — like artificial intelligence, drones, and autonomous vehicles — could even put many more workers out of work. Though we cannot extrapolate from industry to industry, it seems likely that the impacts of automation in retail will be at least as profound as the displacement of manufacturing jobs. As recently suggested by *The Economist*: “The turmoil may also engulf millions of workers. The retailing industry employs 15.9 million people, accounting for one in nine American jobs. The workforce has expanded by about 1 million since 2012, yet a reversal looks inevitable. Since January the industry has shed 50,000 jobs, with more lay-offs sure to come [...] across the world, 192 million retailing jobs are threatened by automation [...].”¹³ While Amazon Go is still in its testing phase and has experienced some technical problems, it is seemingly just a matter of time until it will be open to the public. Meanwhile, drones and robots are gradually taking over more and more work in warehouses; Walmart are even looking to deploy drones to collect products in the stock room and deliver it in their stores. In California, there are now stores deploying service robots to answer customers’ queries. And as e-Commerce continues to expand, more customers are likely to avoid the stores altogether. Thus, highly susceptible jobs such as retail salespersons (4.6 million) and cashiers (3.5 million), which still make up nearly 6% of total U.S. employment, leave plenty of scope for future automation. The headline of a recent *Washington Post* article, “People are worried Amazon will replace Whole Foods workers with robots”, thus speaks to recent trends in technology and its implications for the workforce.¹⁴

Transportation and material moving is no less exposed. Uber may have been a net employment contributor in the past, but this is likely to change: Uber is already experimenting with driverless cars in Pittsburgh. Autonomous vehicles could potentially affect a substantial share of the workforce: Around 3% of the American workforce are drivers of some sort, with truck drivers accounting for the bulk of those jobs. As more data is generated on driving behavior, autonomous vehicles will improve on human drivers: Chevrolet in the U.S. market alone collected 4,220 terabytes of data from customers’ cars in 2016; McKinsey forecasts that these data could grow into a \$450–\$750 billion market by 2030.

¹³ The Economist (2017)

¹⁴ Washington Post (2017)

Figure 172. The Geographical Exposure to Future Automation Relative to Offshoring and Past Automation Exposure

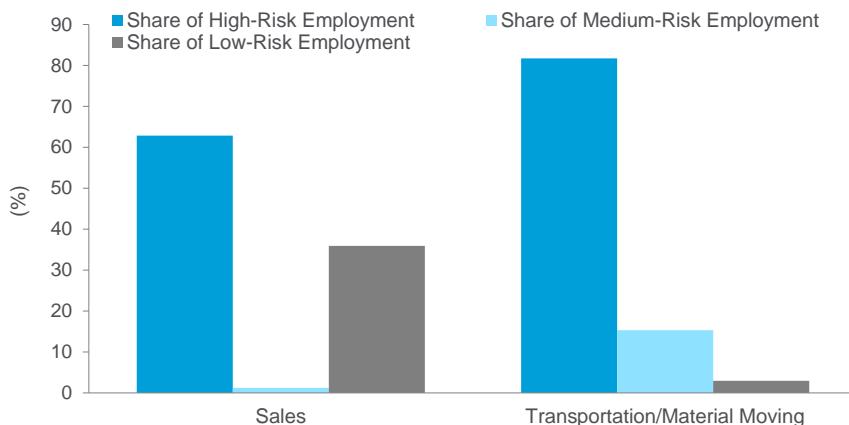


Source: Berger, Frey and Osborne (2016).

Notes: These figures show the share of jobs that are at "high risk" of automation as defined by Frey and Osborne (2017); data on the share of routine jobs and the share of jobs that are easily offshorable as defined by Autor and Dorn (2013). Darker shades correspond to a higher share of jobs at risk.

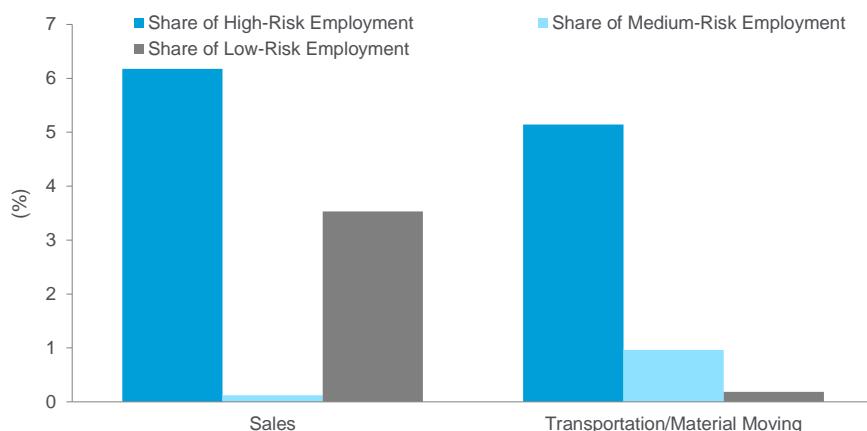
All the same, whether future automation constitutes a continuation of past trends in automation or is a genuinely new phenomenon is somewhat ambiguous. However, a recent paper by Carl Benedikt Frey, Thor Berger and Michael Osborne has shed some light on this matter by examining the geographical overlap between local labor markets' past and future exposure to workforce automation across the United States. An extensive overlap would imply that the expanding scope of automation is a phenomenon whose consequences cannot be distinguished from historical impacts of workforce automation on employment. A limited overlap would suggest the contrary. Though this analysis is limited to the United States, technology is universal, meaning that we can expect to observe similar patterns elsewhere.

Figure 173. Jobs at Risk of Automation (Expressed as Share of Industry Employment)



Source: Based on Frey and Osborne (2013), authors using data from 2015 American Community Survey, collected from IPUMS. The sample includes the working-age (16–64) civilian noninstitutionalized population. Employment is measured as full-time equivalent workers.

Figure 174. Jobs at Risk of Automation (Expressed as Share of Total U.S. Employment)



Source: Based on Frey and Osborne (2013), authors using data from 2015 American Community Survey, collected from IPUMS. The sample includes the working-age (16–64) civilian noninstitutionalized population. Employment is measured as full-time equivalent workers.

Studies have shown that workforce automation will potentially affect a different set of cities and regions than the ones that have historically seen workers made redundant by automation and offshoring

As shown in Figure 172, there is a clear discontinuity in exposure of jobs to new technologies, relative to past patterns of automation: local labor markets with a low share of routine jobs will for the first time find a significant share of their workforce at risk. Moreover, the potential impact of the expanding scope of automation is distinct from the labor market impacts of globalization: there is no significant overlap with the susceptibility of cities to offshoring. In other words, workforce automation in the 21st century will potentially affect a different set of cities and regions than the ones that have historically seen workers made redundant by automation and offshoring. Though there has been much debate about the impacts of trade on the American workforce, fewer and fewer jobs are exposed to trade as most Americans work in non-tradable sectors of the economy: estimates by Spence and Hlatshwayo (2011) show that non-tradable sectors, producing goods and services that are consumed locally, can account for as much as 98% of total U.S. employment growth between 1990 and 2008.

The impact of trade on American jobs is likely to diminish while the impact of automation is likely to increase

Looking forward, the impact of trade on American jobs is likely to diminish, while the impact of automation is likely to increase; the reason being that a substantial share of non-tradable jobs are exposed to automation as a result of recent technological advances. Many of the non-tradable jobs that are exposed to future automation are associated with the retail industry. Within the transportation and material moving occupations, over 80% of employment is at high-risk, and 63% of employment in sales is now susceptible to automation. These jobs also constitute a large share of the American workforce: as shown by Figure 174, the sales jobs at risk constitute 6.1% of total employment in the United States, while the jobs at risk in transportation and material moving constitute another 5.1%. The prediction of President Obama, that, "The next wave of economic dislocations won't come from overseas, it will come from the relentless pace of automation that makes a lot of good, middle-class jobs obsolete," is thus likely to be proven accurate.

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Key Insights regarding the future of Automation and Employment



TECHNOLOGY

Warehouses automation has already increased in areas such as logistics and delivery which has led to increased productivity. / **The real technological disruption to employment will be with the advent of commercial viable automated picking in an unstructured environment, i.e. a robot that can pick up fruit.**



INNOVATION

Robots in warehouses are typically used for de-palletizing, order picking, and goods-to-person movement through autonomous guided vehicles. / **Emerging technologies including flying warehouses, drone delivery, and warehouse drones that can check inventory are still on the drawing board but are possible in the near future.**



HUMAN CAPITAL

In the U.S., retail salespersons and cashiers make up nearly 6% of employment. / **As e-Commerce expands, more customers are likely to avoid stores and retail jobs are likely to nearly disappear while jobs in transportation and material moving (another 5.1% of employment) could fall by 80%.**



