Warehouse of the Future

A White Paper by Arizona State University,
W. P. Carey School of Business

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Executive summary

The rate of change across supply chains is accelerating and the seismic shifts in the market are being felt by manufacturers, retailers, logistics service providers, transportation providers, wholesale distributors and, most significantly, by consumers. These changes and disruptions are a global phenomenon. Current and anticipated changing demand patterns and signals are a root cause of much of this disruption. Consumers have a heightened sense of expectations around visibility and supplier responsiveness.

This report is intended to highlight fundamental changes and trends impacting supply chain practitioners. It examines changes and trends surrounding supply chain technology, material handling automation, facility layout and design, as well as the impacts on processes and the people that are responsible for planning and executing against strategic supply chain initiatives. Supply chain innovation is a driving factor in firm success and there's more innovation than ever before. Speed, efficiency, agility, investments in technology and automation, continuous improvement and strategic HR plans are all traits of today's leaders in supply chain to drive an intelligent and profitable supply chain.

Some of the key trends identified include the following:

- Advances in technology within the distribution center are all intended to help supply chain practitioners address more complex requirements across their supply chain networks. These shifts include:
  - Increased use of robotics in the distribution center
  - Greater use of high density storage and "goods to person" picking
  - Stronger labor supply and labor cost pressures
  - in shaping the adoption of technology in distribution centers
- Distribution center design and layout are also undergoing tremendous change as shippers and suppliers strive to be extremely responsive and agile
  - Continuous supply chain network and optimization is the new norm as companies are forced to respond to changes in the market very quickly
  - Developments such as "PopUp" warehouses, mobile warehouses and "on demand" warehouses are becoming increasingly prevalent
  - For retailers, the store is now viewed as an integral part of their supply chain and is being used more frequently to address the multiple channels they must exploit to address consumer requirements
- Innovation in supply chain software solutions is happening quickly
  - Advances in augmented reality (AR), predictive analytics, via artificial intelligence and data science, cognitive computing, machine learning and real-time sensing across the supply chain are all shaping the supply chain of the future
  - Mobility, Internet of Things (IoT), increased cloud deployments, and even the early influences from driver-less vehicles, are all popping up across supply chains

At JDA, we believe this report will help us all to have more insightful and meaningful supply chain conversations with our peers, trading partners and customers aimed at driving even more intelligent and profitable fulfillment, resulting in competitive advantages that align with overall corporate strategies.

Introduction

It is an amazing time in the supply chain industry. The changes that are coming at managers in the field are both exciting and frightening. There is more change happening at a pace never seen before than any time in the last 100 years. We are in a time of innovation and disruption that is greater than the postwar period that put the US in its preeminent position around the world.

The pace of change is so fast that it is dislocating many established companies and portions of the economy. We have seen elections and movements around the world that are, in many ways, a reaction to these disruptive changes.

In the 1960s it was predicted that, because of technological advancement, the American populace would only have to work three or four hours a day. Workers would be able to relax more because machines would take on the burden of manual labor and tedious tasks. While machines are taking on manual labor and tedious tasks more and more every day, these technological advancements have not resulted in more leisurely lives. Managers do not work 40 hours a week like they typically did in the 1960s and 1970s. Instead, managers and workers are putting in 10 to 12-hour work days and are connected 24 hours a day, seven days a week via phones and computers. They are expected to check in and continue to manage operations all the time. While these changes have many positive impacts, and have greatly improved much of our lives, they are also frightening and unsettling.

Disruptive changes are impacting workplaces around the world and distribution centers have not been exempt from these changes. The simple warehouse still exists in some places, but it appears its days are numbered. Managers are under pressure to bring more efficiencies out of their distribution networks and make the simple become an intelligent, strategic portion of the supply chain.

This report is an examination of the Warehouse of the Future. The simple warehouse is transforming quickly into several different strategic models. This report is an initiative out of the Internet edge Supply Chain Lab (http://research.wpcarey.asu.edu/internet-edge/) at the WP Carey School of Business at Arizona State University. It has been supported by one of the key members of the Lab, JDA, who is the leading software provider in the supply chain space. JDA is a firm that is transforming the planning and execution of supply chain systems.

Organizations are increasingly relying on warehouses as strategic assets. This constitutes a significant departure from traditional views of warehouses as cost centers. This traditional view still exists. In fact, one of the participants in this research recently had a meeting with a Chief Supply Chain officer. This executive said that "we view logistics like an electric utility. We just assume it works until it doesn't work." That is a non-strategic view of logistics and probably a primary reason for cost-based outsourcing. However, more sophisticated companies look at outsourcing completely differently. Amazon is a good example of this sophisticated view. They look at their supply chain including the warehouse as a key competitive weapon in moving past their competition. The ability to deliver quickly has changed how people shop and has become a huge disruption in the retail sector. This disruption is partially enabled by building in new capabilities and analytics into their distribution centers.

In the future, the warehouse will not be built "just to store a bunch of stuff."[1] Firms are not going to design systems where many assets sit idle for a period of time. Thinking about the role that the warehouse plays in the bigger supply chain is beginning to result in different kinds of facilities. We will see more distribution centers designed to be flow through. An example might be containers imported from Asia to a west coast distribution center. This west coast distribution center works as a trans-load cross dock system. Containers are received, processed and then quickly sent to other warehouses or retail stores. The role of these new facilities will be to get inventory in and out as fast as possible while being more tightly integrated with transportation, procurement, and the rest of the supply chain functions. Integration to procurement could involve the use of direct shipments from suppliers through merge-in-transit. The role of the warehouse is evolving to be integrated into

supply chain processes as opposed to simply being places to store excess inventory. In the future, the distribution of goods through such a transload/ crossdock facility will likely be driven by real-time demand signals instead of traditional static models. Companies will work to optimize their inventory positions so that the best product is at the best place at the best time.

The process of researching the Warehouse of the Future has been enlightening. When we began, we wondered if there would really be much to discover about warehouses that, from an external perspective, have not changed much over many, many years. At the end of this research project we have seen our perceptions change as distribution centers are evolving at an incredible pace. As with the rest of the supply chain, warehouses are taking on many new forms and duties.

We want to thank the many executives we interviewed for this project. Many of the interviews occurred on hot summer days when these managers could have easily found other important things to do than talk with a couple of professors. We also need to thank our project sponsor, JDA, for their kind support and help with understanding both the systems that firms are using and the environments in which they operate. We could not have had better teachers than the many firms that talked with us and the JDA professionals that spent countless hours explaining complicated concepts. We are in their debt and grateful for their help. We hope you find the results of this year-long study useful.

Section 1: What has changed or is changing

We are currently witnessing the biggest technological change in the management, processing, and distribution of information since Guttenberg invented the movable type. This is insight was shared with us by one of the executives we interviewed for this research project. Perhaps nowhere has this change been more evident than in the design and implementation of warehouse management system (WMS) solutions. These solutions started to emerge in the 1980s. Back in the 1970s, having a computer in the warehouse was rare. In 1985, one of the authors of this report built a rudimentary WMS for a Fortune 500 company that was still running its warehouse using a paper 3" by 5" card system. Thirty years later, WMS solutions have been implemented almost universally in the U.S. These systems now have much more functionality and are quite sophisticated. But, there is great deal of change on the horizon.

Evolution

During the 1990s and 2000s, WMS solutions would typically be implemented as an add-on to an enterprise resource planning (ERP) system, such as Oracle or SAP. Most organizations would have been either an Oracle shop or an SAP shop. Often, their enterprise architecture would have an ERP system across a single solution with multiple applications. While ERP systems have become an important part of how companies are run, and even organized, these systems have not been generally strong on execution involving demand planning or WMS tasks. Over the last 20 years, ERP suppliers have been working towards building out their execution solutions.

While WMS firms, such as JDA, have an advantage and a head start of several years, ERP providers have been steadily improving their solutions. Most large firms have their ERP engrained in the architecture of all their systems, and that is unlikely to change soon. Typically, after a firm implements an ERP system, they will then begin considering what they want to do for the execution side of the architecture. They will decide if they will install a best-of-breed (BoB) solution or should only implement solutions from their strategic ERP partner. We were told in many of the interviews that a problem with only implementing solutions from a strategic ERP partner is that those solutions really do not provide the capability or rich functionality required on the execution of warehousing tasks.

Increasing complexity in retail

The move to e-commerce has been disruptive because of the complexity that it brings to retail businesses. While a retailer delving into e-commerce may have an entrenched architectural solution around their ERP, they may find out that they will need capabilities that their ERP providers cannot offer at the warehouse, labor, or transportation levels. Before e-commerce, warehousing typically involved moving pallets and cases to retail locations or to customers within their networks. Also, our expectation when we started the research was that we would see more integrated software suites where they would either be supported fully by JDA or by other solution providers. However, this has not been the typical company experience. Most firms are picking and choosing across software providers and have put together a mixed bag of solutions and systems. A mixed solution is primarily due to the previous investment in technology within a firm. Once a linking technology has been selected and installed it is often difficult to quickly replace it even if the replacement might be a better solution. Also, companies have a BoB strategy and implement systems that they perceive to have better functionality even if they do not synchronize easily with other systems that the firm has installed.

With the introduction of e-commerce, the warehouse is being asked to not only pick cases and pallets, but also do more discrete picking, such as inner packs and eaches. The facility also needs the physical footprint within the operation to support these picking tasks when it may not have been designed to support these types of activities. At the same time, firms are feeling pressure to move to e-commerce, change their operations, and perhaps increase the number of facilities, all while the labor market is becoming more competitive. Companies must think about both efficiency and productivity as they move more aggressively to e-commerce. However, in many cases, it is difficult to determine where the journey to e-commerce will lead. Because of Amazon, most firms are feeling pressure to move to a 1 or 2-day delivery timeframe. In some cases, firms feel the need to be able to deliver on the same day utilizing more than one format. Certainly, grocery stores are feeling that pressure as they try home delivery, picking within a store, and "click-and-collect" methodologies.

Section 2: The evolution of warehouse types

One of the most interesting findings coming out of this research is that the symbol of the traditional warehouse is evolving rapidly. Distribution centers have become more strategic and a larger part of a firm's supply chain methodology in satisfying customers. For much of the 1990s and 2000s, supply chain organizations were investing most of their resources into improving their ERP systems and supply chain planning tools. Much of the improvement that could be gained from improving those systems has already been accomplished. As consumer demands are changing and the online portion of a firm's market is increasing, supply chain organizations are looking to their distribution centers to gain additional capabilities and efficiencies. The simple warehouse is much more strategic than it used to be, and more complex.

In this section, we will describe a few of the trends identified during the research project. This section does not contain a description of every type of warehouse, but is designed to describe some of the interesting types of facilities that are emerging and may play a larger role in the future.

Types of warehouses

- **Customer facing**
- **Flow warehouses**
- **High ceiling facilities**
- **Centralized return centers**
- **PopUp warehouses**
- **On demand warehouses**
- **Futuristic facilities**

Customer facing

Because of an increasing difficulty to build large, high volume facilities in central locations where firms can hire labor unconstrained and the increase in online purchases, firms are moving to more facilities that are located closer to population centers. One large apparel manufacturer believes that half of their revenue soon will come from online purchases. Currently, this firm has almost all their warehouse capacity located in and around one large southeastern city. Given that their demand is moving very quickly to a larger portion of online sales, they are working to figure out how to have more distribution centers in their network that are closer to where consumers are ordering product.

E-commerce consumers are not usually willing to wait a week or more for their orders to be delivered. Amazon and some other online retailers have taught consumers that two-day delivery is the norm and same daily delivery is not unreasonable.

The research also highlighted an increasing need to deploy multifunctional facilities that can fulfill brick-and-mortar deliveries, online shipments, overflow management, and cross stocks. Consumer expectations have risen and an important part of competing is being able to get those consumers product quickly at a low delivery cost.

Flow warehouses

One retailer included in the research utilizes an advanced form of crossdock facility. This facility is a "flow warehouse." Apparel is shipped to Los Angeles from Asian apparel manufacturers and is moved to the flow distribution center with a large receiving area and racking. While the items are moved into the retailer's inventory, they do not stay in the facility long. They are quickly moved to stores in malls around the U.S. Each of the planned deliveries into the flow facility are part of a scheduled release that are due in the stores shortly after they are manufactured in Asia.

These facilities require tight coordination of sourcing, manufacturing, and transportation into and out of the facility. The retailer included in the research has invested in tightening down their planning tools to make sure that product gets to the Los Angeles flow facility at the right time. Because planning does not always match execution, their planning tools include the delineation of options to make sure that even if the product is going to be late, the stores do not run

out of inventory. Their planning tools which facilitate the use of these flow warehouses include the ability to move planned deliveries to the stores either earlier or later depending on velocity of product and its availability.

High ceiling facilities

Another trend that is emerging in the warehousing space are warehouses with very high ceiling facilities. In some cases, warehouses are being built that have 40 foot clear or higher ceilings. While 30 foot clear ceilings have become the de facto standard for new facilities for the last 25 years or so, this is a large increase. Moreover, the increasing popularity of these facilities carries important implications for the requirements of specialized material handling equipment such as high-rise pickers.

A primary reason for these high ceiling facilities is that real estate is expensive in many new locations that are to be used with e-commerce. For buildings utilized in an urban center, the number of square feet on the ground is precious. For the same reason that skyscrapers were originally built in city centers, it makes sense to pack more product into urban distribution centers. In the early part of the 20th century many warehouses were in the city center and most of those facilities were multistory and inventory was moved up and down the freight elevator between floors. Today, we know that multiple floors in a warehouse is typically not very efficient.

These high ceiling facilities in addition to requiring specialized material handling equipment, also require special sprinkler systems and support. Firms that move to these facilities find that they can better utilize physical footprint of building, but it comes at a cost of different types of equipment and a more complex picking system.

Centralized return centers

Grocery retailers started building reclamation centers in the 1970s. These reclamation centers were places where old and non-selling product would be sent. In many instances, reclamation centers would be attached to a store. Later, supermarket chains began shipping obsolete or bad products to consolidated reclamation centers for processing. These reclamation centers gave birth to the concept of centralized return centers (CRC).

CRCs are intended to expedite the reverse logistics pipeline and improve the flow of returns. Without a CRC, a firm would accumulate returns and send them back to the manufacturer for their disposition in infrequent, unorganized, large batches. Because returns are not normally the priority of the retail store or the distribution center, returned goods tend to pile up. Inefficient handling results in loss of product value as returned product sits motionless and was often damaged.

Some firms included in the research said that, in general, distribution centers do not work well handling both forward and backward product flows. Many distribution centers that attempt to efficiently process both forward and reverse supply chain flows struggle to manage the returns tasks well. This problem may be related more to focus than to actual capabilities. If the distribution center manager must make a choice between efficiently executing forward logistics versus reverse logistics, it is likely that the manager will emphasize the forward distribution of new product. Also, cycle time processing can negatively be affected when a distribution center handles both forward and reverse shipments. In facilities that only have a few dock doors and limited space on their docks, product coming back can be mishandled or processed slowly.

With the increase of consumer purchases online, the volume of returns has increased. It is likely that firms will need to address the growing number of returns by finding “drains” where they can resell returned and slow-moving product. Utilization of CRCs where the facility is devoted to accumulating and sorting returned product is likely to increase.

Emerging approaches to distribution

PopUp distribution centers

“PopUp” distribution centers are warehouses in a network that are “popped up” on a temporary basis. Typically, these facilities are set up in the months leading to Christmas. They are short term facilities that may be designed to handle a specific product or category, or to give a firm better access to a dynamic market. They are usually designed to respond to seasonality variations.

One multinational third party logistics (3PL) company included in the research utilized one of these PopUp facilities during the holiday season of 2015. This distribution center was used for three months leading up to Christmas to ship headphones that were being sold on a special promotion. The 2015 program was successful and during the 2016 Holiday season the same 3PL was asked to PopUp 10 seasonal distribution centers for different customers and products.

Another example is Amazon, who added 26 distribution centers to its network leading into the 2016 holiday season. Amazon has had a large impact on distribution real estate "Recent leasing data reveals a total of more than 65 million square feet of space occupied by Amazon fulfillment and distribution centers in the US as of November 2016."[2]

While the traditional 250,000 square-foot to over 1,000,000 ft.² large regional warehouses are not going to disappear, there are new forms of warehouses developing. During this holiday season, several "PopUp" distribution centers have developed. These facilities are popped up for three months to service demand that is temporary over the months leading up to Christmas. For many companies, the bulk of their sales occur in the fourth quarter.

It is interesting to note that many more firms are popping up these temporary facilities in comparison to just a couple of years ago. One 3PL company included in the research went from having one PopUp distribution center in 2015 to nine in 2016.

These PopUp warehouses are often part of an "edge fulfillment" strategy, where a firm locates distribution centers close to consumers so they can be served quickly for e-commerce orders. Edge fulfillment is a strategy where the organization positions inventory forward in multiple locations adjacent to customers. In the beginning of edge fulfillment, many of these warehouses are PopUps and are designed to handle shipments primarily during peak seasonality. Over time, many of these facilities will likely become more permanent.

These pop-up distribution centers are more difficult to develop when supply in real estate markets is tight. At the time of this writing in late 2016 early 2017 supply in real estate markets in several U.S. cities was running short. For example, Los Angeles had a 90 percent occupancy rate. This means that there are not many empty buildings that can be utilized for these types of short-term facilities.

A key trend in distribution centers that appears likely to accelerate involves short development cycles that start with the original need for these facilities and result in their quick deployment. This is the result of an increasing need for temporary solutions for the storage of goods to accommodate one-time, in-and-out inventories for seasonal products at retail stores where the need is generally limited to the end of the year holiday season, or in the case of summer products, such as gardening supplies and patio furniture, deployed during the winter and spring.

On demand warehousing

For years, firms have driven their supply chains to be stable, predictable structures. Yet, increasing demands to be more responsive now challenge that approach. Where supply chain leaders were once tasked with reducing costs or increasing efficiency, they are now tasked with transforming supply chains into sources of competitive advantage while reducing costs and delivering a customer experience to compete with Amazon and other e-commerce upstarts. In addition, the tight real-estate market and intensified focus on the bottom line means organizations are less comfortable with unused capacity or expensive and ill-fitting long-term solutions to inventory peaks and valleys. These factor into the growth of on-demand warehousing.

On demand warehousing activates unused capacity across the industry to provide storage handling, and fulfillment services at a large scale through a single software platform and on a variable cost basis. It is powered by software that makes the process of connecting shipper to warehouse provider fast and easy, and provides core WMS features to ensure efficient inventory management, operations and billing. As a result, on demand warehousing produces a scalable and highly flexible spot market companion to the existing "long market" built on warehouse leases or property ownership. In this sense, it is the "Uber" or "AirBnB" of warehousing. On demand warehousing is most commonly used to solve problems related to peak season inventory overflow, supply chain disruptions, and expanding e-commerce or retail fulfillment operations.

One of the early leaders in on demand warehousing is FLEXE, located in Seattle, WA. FLEXE offers a comprehensive, on demand warehousing services solution that connects shippers to a network of over 450 warehousing operators across North America. Cloud-based software enables warehouse search and matching, inventory operations management, billing, and analytics. FLEXE utilizes a unified set of legal terms, insurance, and account support to help organizations make a smooth transition to on demand warehousing, as well as easily add and manage multiple warehouses throughout the year.

FLEXE has found that retailers, consumer packaged goods manufacturers and other businesses that experience sales peaks find significant value in on demand warehousing. This is because of the unique ability it provides to manage multiple inventory overflow projects across the country through a single company and single software platform, with no leases or time commitments. For example, a leading home and garden retailer with a fall and spring peak has been able to significantly increase efficiency within their distribution centers by moving their excess capacity to nearby on demand warehouses through the FLEXE platform. This move to on demand warehousing has enabled them to find and utilize incremental warehouse space and services for as little as 45 days without peak interruptions.

E-commerce organizations employ on demand warehousing to help power a more robust fulfillment operation. These fast growing, dynamic organizations are often unable to accurately predict demand and operational requirements even one year out (let alone five years out) and often do not have the resources required to set up multiple fulfillment centers across the country. By utilizing on demand warehousing fulfillment services from companies like FLEXE, they can "popup" (and down) fulfillment centers to deliver on their customer promise, without risky long term commitments. For example, a large bed-in-a-box e-commerce company utilized FLEXE on demand warehousing for fulfillment to move from a single-node distribution network to a multi-node distribution network across North America without any fixed cost expenses or commitments.

These are only a few examples of current on demand warehousing deployments. But just as Amazon's Web Services (AWS) created on demand IT infrastructure that is now a core part of most firms' IT strategy, on demand warehousing is poised to become a core part of their logistics and supply chain strategy. With the acquisition of Whole Foods, Amazon has suddenly developed edge fulfillment capacity in greater granularity than they previously had before.

Disruptive channels

Disruptive distribution centers

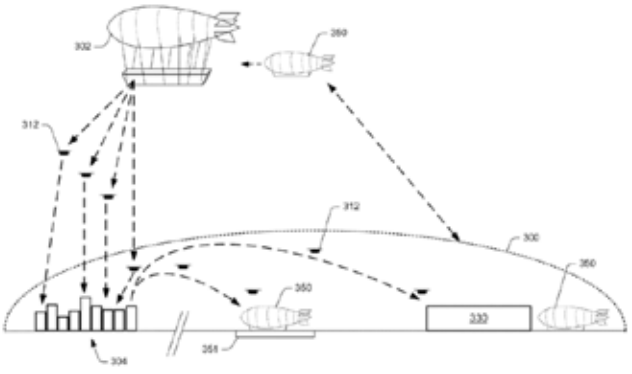
The traditional warehouse is likely here to stay. It is unlikely that the traditional distribution center will disappear. However, there are some disruptive formats that are being tested to see if they could be part of a portfolio of warehouse types. Some of these may be far-fetched and others may not emerge as likely alternatives anytime soon. Nevertheless, if they are technically possible and cost-efficient we could see developments that sound almost crazy right now.

Dark stores

An example of these disruptive distribution centers, are "dark stores." These facilities are retail stores that have been closed usually due to reduced traffic or a change in strategy. A Canadian retailer included in the research is experimenting with using shuttered grocery stores in areas without much density to be an e-commerce facility that provides "click-and-collect" services to customers that drive across the Canadian Plains to buy groceries. With a greater push to put warehouses closer to end-consumers, specifically in cities and more retailers downsizing their in-store operations, there has been a trend to use dark stores to fulfill online orders as well as to retrofit facilities that might have been originally placed in the wrong spot in key urban locations.

Mobile warehouses

Another example of a disruptive facility format is the Amazon blimp. Amazon received a considerable amount of press for experimenting with drones to deliver packages. However, launching drones from a distribution center on the ground and then flying them to people's houses requires a considerable amount of energy. As a solution to this problem, Amazon has applied for a patent for a "warehouse in the sky" attached to a large floating airship. Amazon describes these blimps as "airborne fulfillment centers" with a fleet of drones attached to large airships to float packages down to peoples' homes. Drawings from the patent filing in 2016 are depicted below.



Amazon Airborne Fulfillment Center
This diagram shows a drone delivery process that involves an airborne fulfillment center

Another example of mobile warehouses is truck-based drones[3]. UPS is experimenting with driving UPS vans equipped with drones. While the UPS driver makes deliveries by carrying packages from the truck to the customer, drones carry other packages from the van to other customers. It is way to multiply the efforts of the driver with automated drones that fly back to the UPS van after delivering their loads.

Conclusions

This is an important time in the warehouse industry. Distribution centers are evolving quicker than managers can keep up with in many cases. The warehouse, which was always a small portion of a supply chain, has become more strategic. We are seeing executives work to quickly change their distribution center networks to reflect the fluctuating demands of their customers. Having warehouses that are agile and can adapt to changing conditions in the marketplace and in the supply base is critical. The marketplace appears to be changing at a pace not seen before. At the same time, there is much uncertainty regarding regulation and the simple distribution center is being called on to handle more complexity than it ever has in the past.

While companies are seeing numerous revolutions in their markets and the business environment in which they operate, they are also dealing with changes in labor markets. It is more difficult to staff a warehouse with reliable employees. The number of potential distribution center employees is no longer unconstrained. It is much more difficult to staff a distribution center than it used to be. Also, the perceived quality of distribution center employees has become problematic in many regions.

Section 3: Technology within the distribution center

The adoption of distribution center technology has been driven by the need to cut labor costs, improve productivity, optimize the flow of products, and obtain the highest levels of utilization within the distribution centers' four walls. Historically, the pace of technology innovation in distribution centers has been particularly slow. A major reason for this is that the development and implementation of technology has been driven by long-term investment decisions and other corporate priorities. Often, warehousing and supply chain investments are afterthoughts during the corporate budgeting process. Consider, for example, goods-to-person and shuttle technologies. In both cases, the technology development and implementation cycles in the industry have taken 10 to 15 years from introduction to maturity in most industrialized countries. These cycles are much longer in developing countries where labor costs are usually much lower.

However, technological innovation processes in distribution centers are poised to change significantly over the next few years. In the past, these processes have been defined by large upfront investments and only happened sporadically. In many cases, the returns on investments for these innovation projects could often be recovered in 10 years or more. Moreover, these technological developments have suffered historically from limitations in scalability because, in most cases, a large fraction of their costs has been fixed. Successful future innovations will need to limit upfront investment requirements, be scalable, and make variable costs more relevant in how these technologies are procured and operated.

Distribution center technologies have also historically specialized in addressing the need for either greater efficiency or shorter cycle times within the four walls. Rarely have they focused on improving both efficiency and cycle times. The assumption for most firms has been that distribution centers generally operate in environments where reducing operational costs is the top priority at the expense of operational and delivery cycle times. And in cases where reducing cycle time is the priority, firms need to upgrade efficiency by splitting orders across multiple pick zones and adapt parallel processing to enable narrower order fulfillment windows. In the future, we see a trend to increasingly develop and implement technologies that address the need to improve both efficiency and cycle times inside distribution centers. Lean methods, such as Continuous Improvement and Kaizen have been adopted inside many distribution centers as these techniques developed for manufacturing have been applied to the warehouse. They are delivering tremendous productivity increases as well as cost reductions. The application of these engineering disciplines, coupled with highly sophisticated optimization software (WMS, WES, Labor Management), have dramatically improved distribution center performance.

Future changes in technological innovation in distribution centers are likely to benefit from a recent influx of capital into supply chain technology services. Firms have recently made important investments for a couple of reasons. First, there is an anticipation of increasing demand for more complex distribution. And second, because of demands to respond to greater demands of ecommerce and shorter delivery windows, many companies will have to reconfigure their distribution networks and increase the number and sophistication of their distribution centers.

An example of these new investments is the case of Honeywell and its acquisition of Intelligrated for $1.5 billion in July of 2016. Intelligrated manufactures and installs material handling solutions, including conveyor and sortation systems. Also, venture capital firms are investing in distribution center technology startups like Fetch Robotics and Locus Robotics which are developing robotic solutions similar in nature to those developed by Kiva, which were acquired by Amazon a few years ago. Each of these companies raised over $30 million over the last two years. These types of investments have attracted not only considerable amounts of funding but also operations talent from disciplines such as Physics and Data Science that could spur the development of new technologies and increase the pace of innovation to levels that the industry has not experienced before. For example, Walmart Labs, which contains the ecommerce portion of Walmart, has hired many experts with advanced degrees to help them grapple with the challenges of new distribution center environments.

Warehouse automation

While many types of warehouse automation have been around for a long time, it is still relatively early for new, sophisticated robotic solutions such as those described earlier in this report. There is a need to solve many of the issues facing firms that are trying to automate storage facilities. Much of the automation that has been installed over the last 50 years has been expensive and inflexible. Expensive and inflexible is not a good combination. Companies need to analyze their process flows and structure automation that can be flexible in the long term. Some of the existing technology such as AS/RS or stacker cranes are perceived as too inflexible. Automated guided vehicles have had similar problems. Some companies have made mistakes by only thinking about current needs and not consider how the business and the environment is likely to evolve. One of the firms we interviewed said that "automation providers want firms to hand over their CAPEX and then be done." That is not a realistic solution and is likely to result in a solution that does not last long.

An important reason that firms are re-examining automation in the warehouse is the difficulty to staff distribution centers. One of the interviewees mentioned that when they started up a large facility that contained about $50 million of racking and automation equipment, they required about 200 people a shift to run the building. However, in the holiday season, they needed 2,500. And, it was difficult to find enough people to support the operation.

In areas where many distribution centers are located such as the Memphis area or Eastern Pennsylvania, it becomes difficult to staff when in your immediate area there are, perhaps, 12 other buildings that are one million square feet and need to go from 200-400 people to 3,000 to 4,000 people all in the fourth quarter. Finding short-term employees to operate those facilities can be difficult. Corporate policies require drug testing and background checks that can make a difficult hiring problem unmanageable.

Primarily because of the problem of finding usable labor, companies operating in areas where labor supply constraints are high are increasing the payback on period automation systems in the warehouse. Where traditionally, firms looked for 12 to 18-month payback on warehouse automation, that payback period is starting to increase in North America. In many cases, it is now approaching two to three years, and in Europe firms often look for a five to seven-year ROI for automation systems. This means the amount of capital that firms are willing to invest in warehouse automation is likely to increase. One expert told the research team that recently they have seen more $40 million-$60 million automation being installed in distribution centers than ever before.

Warehousing automation has proven to be very costly because of its constant upgrade, maintenance and daily management requirements. Moreover, storage and warehousing systems require a modular approach and a different mindset than before. This is because many markets have historically experienced a great deal of excess storage conditions. However, as e-commerce expands, these realities are likely to change. Some of the people interviewed for this research believe there will be a massive shrink of physical space over the next five years.

Retail automation

For many companies, a likely scenario is that they will put together a network of hybrid distribution centers that include automation, semi automation, and manual processes. According to some of our research participants, hybrid distribution centers will be supplemented with specialized fulfillment centers and on demand warehousing. A reason is that online retailers usually manage a lot of different SKUs compared to traditional retailers. It is not atypical for a retailer such as Amazon to handle massive numbers of SKUs. One retailer told us that they expect to handle 2 to 3 million SKUs. This type of assortment is difficult to maintain in one facility, so the warehouse network needs to consist of different types of facilities where some of those distribution centers are close to the customer. Some of these retailers maintain a wide and shallow inventory assortment which drives a set of distribution center needs which are quite different from a retailer that provides a narrow band of SKUs but is very deep in terms of quantities on hand

One leading e-commerce pure play company included in our research believes that the U.S. retail store footprint is likely to shrink substantially. It has been estimated that out of the 1,100 standing shopping malls in the US, about 700 or 800 will be viable five years from now.[4] Smaller stores, or convenience store chains such as 7- 11 or Circle K are likely to be more successful because they are not held back by significant cost commitments associated with large retail holdings.

Another e-commerce pure play company senior executive also believes that fewer fulfillment centers will be needed. He told the research team that the customer will make the choice in speed versus. cost, and the firm will need to strive for optimality in the consumer's chosen approach. One option is "click and collect" because it is cheaper as it takes out last mile delivery costs. This may be one of the reasons that Amazon recently chose to purchase Whole Foods, a brick and mortar grocery retailer. It will allow Amazon to quickly develop a "click and collect" network for food and consumer packaged goods which could greatly improve delivery speed and, maybe, take costs out of their current delivery options.

If we project future demand and examine it from a consumer behavior viewpoint we can see what future distribution networks might look like. Instead of distribution centers that just handle pallets or cases, a retailer will need to have more flexible, nimble distribution nodes that are capable of performing multiple functions. They will fill cases, pallets, or eaches and will need to switch between those different types of shipments smoothly.

Some of our research participants believe that, in the future, brick and mortar retail stores will still be important. Retailers that have brick and mortar stores in place have begun to use these stores as part of their distribution networks. As omni-channel retailing grows, we may witness a complete blurring of all these channels and the facilities supporting them will become part of one fulfillment model. In the future, it will be necessary for optimization software to sit on top of distribution networks which will identify where inventory is located regardless of whether the inventory is owned by the firm, the wholesaler, or the retailer, or whether it is located upstream in a supplier facility. Based on cost parameters and fulfillment promises made to consumers, analytics will plan how to deploy that inventory. Utilizing predictive analytics, future networks will allow users to deploy inventory before the customer signals they want it. Inventory will be strategically deployed across the supply chain in a predictive manner. The future network will consist of several different types of nodes that will require flexible, agile software that can operate out at the Internet edge. This software will be enabled through predictive analytics that barely exist today.

Most retailers have never had to achieve this level of service. This means that the firm has to address increased complexity where instead of standard weekly deliveries to one location, a shipper must figure out how they optimize their supply chain both upstream and downstream from the distribution center. They have to figure out where in the network to drop an order to the local facility that is close to consumer because of cost, efficiency and service delivery levels. The capability around shipping individual units instead of pallets is complex for a shipper, particularly if the inventory is located upstream in the supply chain. Typically, a firm picking individual units would install automation. This automation could include sortation equipment but may also include pick-to-light, put walls, and voice picking so that warehouse employees can use hands-free picking. Getting that kind of automation in place where units are packed, presented correctly in the package with the appropriate label production then shipped out the door can be extremely challenging. Rich capabilities that include complicated value added services require flexibility. This type of complex automation has been difficult to support in the past for some of the ERP or smaller (Tier 2) WMS vendors.

Another complexity factor is the regional environment. For example, people in the UK think differently about shopping than people in the US do. Typical homes in the UK have smaller storage space than those in the US. So, purchase amounts are typically much smaller in the UK than in the US even though the logistics costs associated with larger product bundles may be lower in the US because of economies of scale. Households in the UK typically shop every day. This means that inventory replenishments at stores and warehouses in the UK will be different than those in the US. As firms have globalized, they are seeing a myriad of market and cultural environments that also drive the shape and cost of their supply chains. Most multinational organizations realize that there is not going to be one strategy that they can easily apply globally. The notion of defining global, rigid processes that come out of a standard ERP is fast becoming obsolete. We are moving to business processes that are much more intelligent, embedded, adaptable, agile and resilient.

Next generation automation

The remainder of this section will describe technology applications that will address many of the technological development shortcomings experienced in the industry and highlighted above. These applications have been built on the need to limit investment requirements, reduce limitations in scalability, and make variable costs more relevant in how technologies are implemented and operated. They have also addressed the need to improve both efficiency and cycle times inside distribution centers as opposed to advancing efficiency at the expense of cycle times or vice versa. Moreover, they have added new capabilities to help solve known complex problems in the industry. Although the applications vary slightly in their readiness, they have been tested in the field successfully and have shown the potential to provide early adopters with considerable competitive advantages.[5]

Autonomously guided vehicles (AGVs)

Historically, AGVs have referred to Automated Guided Vehicles. But new AGVs are emerging. These AGVs are Autonomously Guided Vehicles, which are different and much more flexible than the old AGVs. AGVs use radar, LIDAR[6], camera scanning, and ultrasonic and infrared sensors to route themselves without predefined paths. AGVs create maps within their own databases and are continuously updating them because they are aware of their changing surroundings. They are similar to the self-driving cars and trucks that have begun to appear on the road. AGVs can appear on-demand, adapt to changing directions, and adapt to barriers or obstacles that move in and out of their routes. This allows for flexibility and quick deployment without the need for significant changes in infrastructure inside distribution centers. It also offers the opportunity to use these solutions on demand inside distribution centers for short term periods or during peak seasons.

AGVs address key limitations of earlier systems, like Kiva robots, that use fixed paths that are costly to change once they are installed. They also improve upon more basic solutions that are limited by simplistic routing and low level decision making capabilities. These basic solutions used to include elements, such as wire mounted lifts, permanently mounted reflectors, beacons, barcodes on the floor, or magnetic tape for the "old AGVs." These are all fixed and used sequential routing and tracking which was quite inflexible and expensive.

There are two major application forms of the "new AGVs" in the market. The first one focuses on retrieval of full cartons from storage racks. The second one focuses on unit picking. These solutions use AGVs that can plan and react dynamically based on changes in their environments as well as from feedback received from other AGVs in the system. Three companies that have led the development of these solutions are Symbiotic, for full case retrieval, and Clearpath Robotics and Karis Pro, for single unit picking.

Vertical, full case picking applications

Shuttle systems have dominated the technology space for vertical, full case picking applications for over ten years. These systems evolved from automated storage and retrieval system (AS/RS) technology introduced in the 1960s. They use lifts that traverse the different levels of the shuttles and conveyor infrastructure (sometimes referred to as the "loop") that couples the storage and the pick modules between levels. The problem with both vertical lifts and loops is that they frequently create bottlenecks in the flows of shuttle systems. Several companies are developing technology applications that address these constraints. Some of them are working on embodiments of shuttle technology that do not have conveyor loops. Each shuttle has its own lift, work stations are placed around the perimeter of the storage, and shuttles are no longer bound to fixed paths, to a lift, to conveyor loop, and then to a workstation. Movement is not independent to each shuttle, and the shuttle has three dimensions of travel available to it.

Other companies, like Bionic Hive, have developed solutions that eliminate the need for traditional forklifts in vertical, full case picking environments. This solution replaces fork lifts for small, autonomously guided units that attach directly onto the pallet racks (Figure 1.4). These units can move vertically and laterally on the racks and have extendible arms that enable them to retrieve cases from shelves at high altitudes. Beyond reductions in labor costs, a key advantage that this solution provides is that it is easy to implement in all kinds of warehousing environments, including those with narrow aisles, high altitude racks, and misaligned shelves.

Autonomously Guided Vehicles (AGVs)

Robotic picking applications

There is a confluence occurring between labor and robotic picking technology. The task of picking typically accounts for 55 to 65 percent of the total labor cost of warehousing operations[7]. These costs are projected to increase over the next several years. A number of states across the country have increased the minimum wage to $12 and $15 per hour. Moreover, access to labor has become increasingly challenging in areas where distribution centers operate, particularly urban centers. According to a recent Fortune article, 1.4 million workers will be needed in distribution centers and other areas of the supply chain by next year[8]. One problem is that the distribution industry, which has typically been a low-wage job, is not highly visible or interesting to many job seekers. Moreover, even if job seekers are aware of this industry, they are likely to hold an outdated image of noisy forklifts driving through grimy warehouses. These labor challenges are in stark contrast against the quickly decreasing cost of robotic technologies. This is not just limited to North-America and Europe. In places like China, rising wages, difficulties hiring and keeping workers, and cultural shifts are expected to dramatically increase demand for robots[9].

The rise in popularity of robotic applications is partly the result of an increase in access to machine learning and cognitive computing, the generation of data in distribution centers by the Internet of Things (IoT) and sensing networks, as well as an increasing awareness by decision makers of the availability of these data. Consider robotic arm applications for the retrieval of products from shelving bins. During the process of retrieving an item from a shelf, the brain makes many decisions. These include establishing which products are within reach, evaluating the product attributes, and establishing which specific product to pick. These are decisions that machine learning and cognitive computing can help address, particularly in environments in which only a handful of products can induce a large amount of complexity. The difficulty does not lie in the requirements necessary to program the robots. The complexity resides directly in the product itself. The product can be fragile or reflective. It could also have irregular shapes or be geometrically inconsistent. All of these factors amount to infinite variability, degrees of freedom, and difficulty in development and implementation.

These problems are now being solved with an evolving array of cases around product picking, decreasing costs of vision and 3D (three dimensional) sensing technology, and advancing software. RightHand Labs has designed and piloted a robotic arm solution, called ReFlex, for “each” picking that aims to successfully address real-world picking demands in narrow warehousing spaces, such as those occupied by shelving units at Amazon’s fulfillment centers. The solutions evaluated in this application area differ in their mechanical designs[10]. They range from large, static single-robot arms to mobile two-arm robots. The latter type of design offers a more scalable solution and can run both arms in parallel to achieve faster picking when multi product orders are involved or in environments where products that need to be picked are obstructed by other products in the shelves. The solutions also differ in the design of their gripping capabilities. Some solutions use friction (finger gripping) designs while others use suction designs. While suction designs cannot easily rotate or manipulate products in highly populated shelves, they are more versatile than friction designs because they can accommodate a wider variety of product shapes and sizes.

Most applications in this space use visual perception solutions based on structured light for 3D perception. These solutions give robots the ability to process 3D object surfaces through the use of light-based coding methods[11]. They also build on open source tools such as Point Cloud Library (PCL) and Open Source Computer Vision (OpenCV) to cover basic sensing needs. PCL and Open CV contain machine learning algorithms that facilitate the filtering, feature estimation, surface reconstruction, registration, model fitting, and segmentation of 3D imagery[12]. However, as product density in shelving bins increases, sensing systems require more advanced vision software to be able to differentiate among products. Planning and control designs for these solutions are highly specialized to different environments. One objective is to maximize picking productivity by minimizing trajectories and by taking into consideration the ordering of products in different shelving units. Picking rates at Amazon average five seconds per item, according to Cornell et al. (2016). Matching that speed with robotic picking solutions will make the business case for these solutions more compelling. Another objective is to offer high levels of picking reliability, at least comparable to those by humans. This involves reducing errors, such as those involving misclassified products or dropped items. It also involves the detection and correction of these errors.

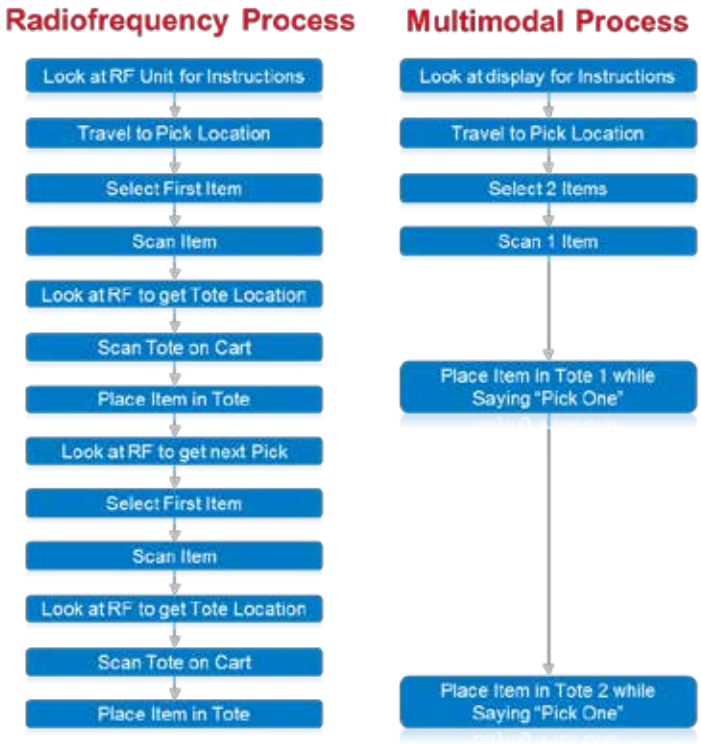
Two other companies that have developed and piloted cutting edge technology applications in order picking are Locus Robotics and Fetch Robotics (Figure 3.2.). Both companies' applications are based on autonomously guided vehicles with order picking assignments. This approach at order picking improves efficiency because it enables orders to be brought to pickers, significantly reducing walk time. But, this is not the only benefit. With increasing volumes and productivity demands constantly shaping order picking solutions, these applications are easily scalable, and can route the picking of orders through multiple zones without increasing cycle times. This is because they are not tied to conveyor infrastructures or serialized processes. Moreover, in the case of Fetch Robotics, it is possible to perform each picking directly into totes that are handled by autonomous robots. Another advantage is that Fetch Robotics' applications can increase work content to improve picking productivity using static shelving features that that can be added on top of the robots to increase the number of orders that robots can pick at any given time.

Locus Robotics and Fetch Robotics Solutions

Multimodal picking applications[13]

Multimodal picking augments voice picking with vision picking. The latter may be based on heads-up displays that can be embedded in wearables, like visors or glasses, and provide the user with computer-generated data that is displayed in a part of the user's field of view. These wearables are beginning to infiltrate distribution centers. Google Glass is an example of this technology. The early results are generally positive. By using this technology, a worker walking through a pick zone can see the next pick in his augmented view and be guided on an efficient pick path.

DHL has invested heavily in the development of this technology over the past two years and has started implementing it for use in its distribution operations. Currently, DHL is rolling out multimodal picking in several distribution centers running on a variety of warehouse management systems (WMS). Multimodal picking has replaced picking based on radiofrequency devices in these sites. The figure below provides a comparison between of the picking processes based on radiofrequency and multimodal technologies.



DHL reports several benefits from heads up displays and voice directed warehouse tasks. First, visual navigation directing the picking process in the picker's line of sight allows more uninterrupted movements. Second, visual confirmation reduces scan time and errors. Third, users can perform pick processes more freely and with less ergonomic stress. Fourth, the combination of visual and voice interfaces drastically reduces training time for seasonal and temporary workers. Fifth, multimodal picking is language-independent because it allows users to set profiles and choose a preferred language from a variety of options. Finally, because these applications do not require investments in pick to light infrastructure, they are highly scalable and their implementation is a lot less capital intensive.

Future implications

Thus far, the road to automate distribution centers has been littered with obstacles such as high cost, inflexibility, and non-scalability that have made the adoption of technologies for seemingly simple tasks, like picking, difficult. This is reflected in the low rate

of automation in distribution centers in industries like grocery retailing, where only 8 percent of warehouses owned by the largest retailers are automated[14].

The key question is whether the technology applications discussed in this report will change this reality. To do so, they must address several technological development challenges that have plagued the industry. First, they must limit upfront investment requirements that can easily reach tens of millions of dollars per warehouse. Second, they must reduce limitations in scalability and make variable costs more relevant in how technologies are operated. Third, they must address the need to improve both efficiency and cycle times inside distribution centers as opposed to advancing efficiency at the expense of cycle times or vice versa.

Interest in warehousing automation has been driven by recent increases in demand for labor and costs. It is estimated that there are currently almost 900,000 employees working in warehousing related tasks in the U.S. This number has increased quite dramatically over the better part of the last decade, according to the Bureau of Labor and Statistics (figure below)[15]. Moreover, over half of the current employee pool in the warehousing industry work directly in labor intensive activities involving stocking, picking, and order assembly[16] and the number of workers in this occupational area is expected to continue to increase at a five percent rate over the next ten years[17].

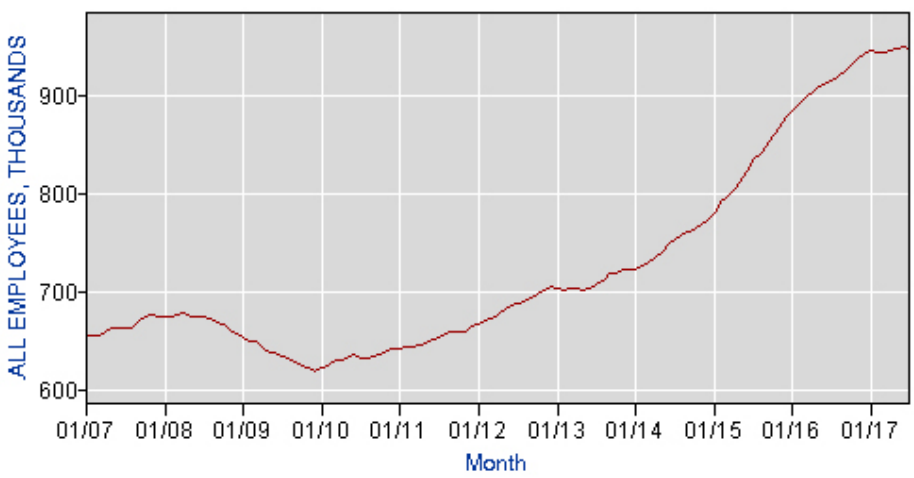
It remains to be seen whether this new generation of automation solutions will lead to a decrease in the need for labor in distribution centers. The demand for warehousing labor keeps on increasing because economic output is on the rise. But this trend will not continue in the future. Technology adoption must take this into consideration.

Rather than replacing workers entirely, the focus should be on using technology to make workers more productive and their jobs easier and safer. Amazon, for example, claims that Kiva robots enabled them to reduce by one hour the average order cycle time in their fulfillment centers[18]. Locus Robotics has indicated that their solutions can improve upon these gains because they are up to 75 percent faster than Amazon's Kivas[19]. Fetch Robotics also claims their solutions are designed to allow warehouse pickers to stay in their jobs longer by reducing the physical demands that picking tasks have on their bodies[20]. This can lead to a decrease in labor turnover rates, savings in training costs, and reductions in productivity losses when on-boarding new employees. Automation could also contribute to reduce workplace hazards. This is a particularly relevant issue in the warehousing industry, where the 5 out of 100 employees suffer work related injuries involving days away from work, job restrictions, or transfers every year[21].

Conclusions

It is premature to think of automation as a mean to replace workers. Instead, it is more likely that in the more immediate future automation will serve to expand workers' capabilities, enrich their jobs and make them safer, and contribute to maintain their productivity for longer periods of time. However, distribution centers are under pressure to cut labor costs, improve productivity, optimize the flow of products, and obtain the highest levels of utilization, which is the driver of these new technologies within the warehouse. It will be interesting to see if the technology.

Seasonally Adjusted Time Series for the Number of Warehousing and Storage Employees in the U.S.



Section 4: Systems evolution

Integrated solutions

While ERP software companies can struggle with execution solutions, integrating planning supply chain software, together with execution solutions such as WMS, can help optimize the supply chain. This means that a firm with integrated supply chain planning and execution solutions can be "constraint aware.[22]" Because of this type of awareness, a firm can determine critical information across several different software platforms and optimize for a total systems solution. Integrated supply chain solutions can optimize across more than one application. Firms can manage across software such as demand planning, forecasting, distributive order management with transportation, warehousing, labor management and be "intelligent fulfillment constraint aware" from a warehousing perspective. A firm that is "intelligent fulfillment constraint aware"[23] can analyze input parameters based on operational best practices and then figure out how to optimize that within the warehouse.

In the future, having integrated supply chain solutions across planning, inventory management, transportation management and warehouse management will be a requirement. Software solutions will need to be constraint aware to provide a real end-to-end solution. Many customers today cannot take advantage of integrated constraint aware solutions because they have not yet invested in software that will work together very well, or they have ERP solutions that are both expensive and difficult to adjust.

WMS solutions are also increasingly moving to the cloud. It has been predicted that by 2020, 90 percent of spending on new WMS will be in the form of cloud-based systems. System deployment time and complexity has been greatly reduced, and reliability has improved. Moving to the cloud has resulted in greater organizational flexibility because necessary infrastructure to roll out a WMS or other supply chain system does not have to be continuously rebuilt for each application of the system.

WMS, WCS, and WES

To extend the execution capabilities of WMS solutions, firms have sought to implement warehouse control systems (WCS) and warehouse execution systems (WES) solutions inside their distribution centers. Not surprisingly, given their ubiquity, there has been a fair amount of confusion around the differences among these solutions. In this section, each of these solutions are described. WMS are software solutions that companies purchase to manage all the operations in the warehouse, and they are used to interface with other solutions that companies utilize. Dwight Klappich, a leading analyst from Gartner defines a WMS as "a software application that helps manage the operations of a warehouse or distribution center. WMS applications offer capabilities such as receiving, put-away, stock locating, inventory management, cycle counting, task interleaving, wave planning, order allocation, order picking, replenishment, packing, shipping, labor management and automated materials-handling equipment interfaces.[24]"

WCS are smaller, more specialized solutions that typically sit on top of WMS solutions. Their objective is to manage material handling technologies such as conveyors, automated storage and retrieval systems (AS/RS), carousels, scales and sorters, etc. These are automation equipment subsystems that need direction that is typically independent from the WMS. A WCS contains logic so that WMS and ERP systems do not have to manage all the intricacies of the automation equipment subsystems.

Most WCS solutions have traditionally dealt with conveyor-based systems. They manage sortation and transportation routing on conveyors and the routing through pick modules with, for example, zone transfers that deal with scales and weight checking.[25] WCS solutions facilitate the automation so that WMS can handle inventory management, order management, and other warehouse system tasks. WCS are typically sold by either the company that is selling the material handling equipment, or by a third party solution seller that is unable to connect the material handling system to the WMS.

Some WCS solutions have increased functionality and have taken on small portions of WMS functionality. These enhanced WCS solutions have become the foundation of more comprehensive WES solutions.[26] WES solutions include material handling management and control capabilities. They also include intelligence so that the picking and put away functions can be optimized within, for example, a pick-to-light or put-to-light system, or another material handling system. A WES augments the WMS when it comes to items like waveless order picking. Waveless order picking can be critical if the firm is moving to an e-commerce environment and picking individual units instead of pallets.

The move to omni-channel retailing means that warehouses are less able to batch orders into large waves. WCS providers are becoming more aware of the operations beyond the material handling technology and so WES solutions are being developed to blend functionalities between WMS and traditional WCS. These WES are smarter, more aware of what is happening in the facility.

For larger, complex operations that include automation, both a WES and WMS are going to be needed. WES is not usually going to be a replacement for WMS. And, in the future, WMS will include enough intelligence so that WCS/WES can be rolled into the WMS solution. This integration could relieve some of the pressure off implementation. If a firm has heavily automated solution needs to be integrated with their management systems, approximately 20 percent of their effort on the project will be applied to simply enable integration.

In the future, there may be standard messaging systems developed that will allow for simpler integration of warehouse or manufacturing automation and their management systems. These standard messaging systems could look something like EDI transaction sets.[27]The warehouse execution of the future will likely include artificial intelligence capabilities such as cognitive computing and machine learning, and may also contain automation control systems in larger amounts than they do currently.

Analytics

Optimization and analytic systems are being built into WMS systems and their connected software. So, if it is more cost effective to ship from a supplier to a store than supplier to a customer the optimization and analytical systems should be able to sense the resources and constraints and execute to best outcome.

Fast flow distribution models that result in lower inventories and greater delivery speed can also add complexity. If firms could apply analytics to optimize the flow within a complex merge in transit distribution model, they could inform the network how to act, and then create the needed merge capabilities within the distribution center.

As we argued above, warehouses are going to not simply be buildings where inventory is stored. Instead they will be flexible and intelligent facilities which will assist the firm leveraging the inventory they have across the system regardless of where it is located. They will help to avoid creating new islands of inventory and new unnecessary routes to the customer. Their channels will need to converge so that firms can move and position inventory dynamically and not statically.

Through WMS and other related solutions, there may be a way to receive items and not specifically identify the destination or channel. Based on a layer of analytics, the system will pull the product based on a demand signal in a cost-effective manner. Automation will facilitate based on predictive analytics.

It is likely that analytics are going to help coordinate movements and storage locations within the warehouse, but also have an impact beyond the four walls of these facilities. In the future, analytics will help manage inventory across the supply chain system and not just inside each facility. Ideally, they will contribute to define routes to customers and identify locations where items should be placed. For instance, if a firm has a retail store presence, the warehousing capabilities of the future will require having strong analytics to not only optimize order fulfillment but also sort, assort, and place inventory in the right locations. If a firm has slow moving items that are fast moving in one supply chain location and those items are not placed at stores or vendor warehouses at the right time, they will draw excess costs.

Cognitive computing/Machine learning

The emergence of future analytics capabilities will depend on the ability to collect and analyze increasingly massive amounts of information. This trend in analytics, commonly known as Big Data, is beginning to find its way through the enterprise. We are beginning to see new types of technologies and system elements be implemented that can analyze massive data amounts in a wide variety of ways. We are starting to see not only supply chain analyses come alive in ways that were not possible before, but also analysis actions being executed in ways that could only take place before at the direction of human beings.

This kind of environment lends itself to the application of cognitive computing and machine learning. Machine learning has become pervasive. We see it when we type question into Google or go to Amazon and receive recommendations for books. This same technology is moving into warehouses and is likely to become a major competitive tool in the future. Pioneering organizations are beginning to lean heavily into artificial intelligence and predictive analytics. We are beginning to see smart WMS that utilize cognitive computing. There is going to be substantial impact on the warehouse as predictive analytics will assist in several functions including placing inventory in the right place in the supply chain. Because of smarter systems such as WMS, and the increased amount of data that can be analyzed, an “unlock of tremendous potential to improve supply chain effectiveness has started to occur”[28] that is moving quickly to change how firms manage their entire supply chain. It is likely that the first to implement these technologies successfully will see important wins.[29]

Conclusions

WMS is evolving from software that is used to manage receive, put away, locate, pick, and ship products in a simple manner to sophisticated systems that allow for “what if” analysis and tight integration with the rest of the firm and its supply chain. WMS solutions are increasingly under pressure to operate in environments where labor supply is tight and more difficult to manage. Companies are viewing their WMS as strategic investments to enable them to compete.

Companies are under pressure to reduce costs while increasing delivery velocity. This pressure is happening at the same time the market is changing their expectations and is demanding new, efficient solutions. Customers have high expectations and little patience. It is no wonder that logistics leaders feel like they are in the middle of a hurricane.

Closing remarks

It is very clear that disruptive changes, as well as technology innovations in supply chain, will continue to be the norm for the foreseeable future. The global e-commerce market is estimated to be $1.915 trillion and, "according to eMarketer, annual global e-commerce sales will more double over the next four years, to about $4.1 trillion![30]" Today, retailers are forced to compete with global e-commerce companies that don't own any stores. Manufacturers and brand owners are facing tremendous changes to the way they forecast and plan in response to shifting demand signals driven by ever-changing consumer buying habits that ripple back through the supply chain to the manufacturers. Companies that are unable or unwilling to adapt to these changes in the supply chain market will struggle to survive. Material handling solution providers will continue to develop more sophisticated robotics, as well as intelligent self-driving vehicles in response to looming labor shortages that distribution centers are facing today and that are predicted to continue. Employee engagement is top of mind for most major employers as the global, aging workforce continues to shrink, thus driving the need to have a strategic HR "people plan," whether it is in the distribution center, the store, the factory floor or the head office.

The warehouse of the future will be much different than we have seen in the past. Innovation is driving an increase in the number of patents and solutions involving technologies, such as delivery drones, augmented reality, IoT sensing technologies across the network, all the way down to the factory floor and retail shelf level – and most of this is happening in the cloud. Continuous improvement is essential across all phases in the supply chain as companies are constantly re-examining ways to optimize, virtualize, plan, execute and service their customers in the most intelligent and profitable manner. Yes, there will be winners and losers as these disruptive innovations continue to be developed. There will be tremendous opportunities at all levels, whether it is the way a distribution center is designed and automated, or how the supply chain network processes are optimized, or how manufacturers, retailers, wholesale distributors and logistics service providers continue to collaborate and innovate to address these tremendous market changes and challenges. Clearly the "warehouse of the future" will be unlike anything we have seen in the past, and will continue to be a very strategic component in the larger supply chain network.

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