NEW SUPPLY CHAIN TECHNOLOGY
BEST PRACTICES

THE APPLICATION OF NEW TECHNOLOGY IN THE PHYSICAL SUPPLY CHAIN

A WHITE PAPER BY THE UNIVERSITY OF TENNESSEE, KNOXVILLE,
HASLAM COLLEGE OF BUSINESS SUPPLY CHAIN MANAGEMENT FACULTY

APRIL 2017
Supply chain professionals now clearly see a tsunami of new technology coming at them and are scrambling to develop a strategy to deal with it.

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NEW SUPPLY CHAIN TECHNOLOGY
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THE APPLICATION OF NEW TECHNOLOGY IN THE PHYSICAL SUPPLY CHAIN

THE FIRST IN THE TECHNOLOGY IN THE SUPPLY CHAIN SERIES OF
UT’S HASLAM COLLEGE OF BUSINESS SUPPLY CHAIN MANAGEMENT WHITE PAPERS

APRIL 2017

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Foreword

The purpose of this paper is to provide you with information about five new innovative technologies that could greatly impact your supply chain. We designed the paper to provide guidance on successfully navigating the innovation landscape for these technologies. We will delve into the many benefits of each technology as well as some challenges, and we will give you a peek into an amazing future.
Introduction

An unprecedented wave of innovation engulfs today’s supply chain professionals, and they know that they will have to adapt to survive. New breakthrough developments, such as drones and driverless vehicles, seem to be everywhere. One government estimate notes that new and emerging technologies could generate hundreds of thousands of new jobs and hundreds of billions of dollars for the economy over the next ten years. Whether a company wants to be on the leading edge with these new concepts or not, we strongly believe that all firms must stay abreast of the rapidly moving developments in these fields. They can lead to market differentiation, competitive advantage, and stronger brand awareness and can eventually create greater customer satisfaction, sustainability, and employee engagement. Both of the sponsors of this whitepaper and many others have proven this with innovative solutions that are being implemented today.
Categories of Innovation

It’s safe to say that we have never seen a time with so many developments that could immensely impact the supply chain. They fall into two broad categories:

1. **Informational/analytical innovation**: Cloud computing, big data, and cognitive analytics to capture, store, analyze, and derive insights from data, disseminating and capturing data generated by the Internet of Things (IoT).

2. **Physical innovation**: Technologies that take a more physical form: drones, driverless vehicles, robotics, smart glasses/augmented reality, and 3-D printing.

In this white paper, we will focus on the physical innovation. However, the segmentation is arbitrary, and clearly the two categories are inextricably linked. Integrating the physical side of innovation with the digital technologies through advanced software will generate the data needed for optimization. This connectivity will allow machines to learn and expand their range of application dynamically—rather than remain constrained to a fixed, narrow range of application—leading to a dynamic, automated learning environment.

This is the kind of innovation that leading supply chain software providers such as JDA Software, with their innovation lab based in Montreal, explore and apply using their dedicated team of data scientists and engineers. This technology will add incredible visibility to the supply chain, and that visibility, when coupled with the new physical devices, will result in step improvements in customer service, inventory, cost, and supply chain excellence.

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**Figure 1**

**SUPPLY CHAIN INNOVATION**

- **Physical**
  - Drones
  - Wearable Technology
  - Driverless Vehicles
  - Robotics
  - 3-D Printing

- **Digital**
  - Internet of Things
  - Big Data
  - Cognitive Analytics
  - Cloud
  - Supply Chain Digitization

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In a 2016 SCM World survey, respondents felt that the information/analytical category would significantly affect the supply chain in the relatively near future. For the physical side of innovation, respondents thought that the most impactful and disruptive technology would be robotics, followed by driverless trucks and drones.

The participants in this 2016 survey show a growing sense of awareness and urgency around all of the new innovative technologies. They expect all of the new innovation areas to be much more impactful on their supply chain than they did just two years ago in the 2014 survey. Supply chain professionals now clearly see a tsunami of new technology coming at them and are scrambling to develop a strategy to deal with it.

Some of these technologies will have a relatively quick and major impact on the supply chain, resulting in cost and customer service breakthroughs along with an increase in cash flow. Some will have less impact, and some will slowly evolve. For example, radio-frequency identification (RFID) burst onto the scene in 2003, and many expected it to have a major and immediate effect on the supply chain. It failed to live up to expectations due to cost and accuracy issues. Now RFID is clawing its way back with more and more supply chain applications. It may go this way for some of the new technologies, or they may have an impact that will rapidly upset the competitive landscape. The question is: which ones should we bet on for rapid change now?

Based on discussions with the numerous industry experts for this white paper, the majority believed robotics will have the most immediate impact on the supply chain. Other physical innovations were considered more distant with respect to timing. After robotics, the participating industry experts listed driverless trucks, followed by drones, then wearable technology, and lastly 3-D printing. It is anybody’s guess now and highly controversial, but the consensus we heard can be represented in Figure 2. Note that this ranking also seems to be reasonably consistent with the Garter study, *Hype Cycle for Supply Chain Execution Technologies-2016*.

All these new technologies are exciting and cool, but hardened supply chain professionals know they will have to be coupled with a compelling business case to withstand the test of a rigorous ROI analysis and ultimately get to wide scale, go-live status. Innovative supply chain professionals understand the need to keep their finger on the pulse of the dramatic change sweeping the field. They also understand the need to be ready and able to move quickly, if necessary. Moreover, they know that technology usually advances faster than business, governmental/regulatory, or societal changes.

*For the physical side of innovation, respondents thought that the most impactful and disruptive technology would be robotics, followed by driverless trucks and drones.*
Today, these physical innovations do not yet have a clear business case for large-scale roll out. Nevertheless, hosts of companies are experimenting with them to understand their potential and how their business can change for the better when these technologies are successfully adopted. For example, Kenco has performed significant research and testing with their innovation lab on the use of drones in warehouse and trailer-yard management, providing both accurate and fast inventory visibility.

It is daunting to try to estimate the impact of these technologies on supply chains. This white paper takes a snapshot of the current thinking by tapping a wide range of expert sources, including a number of large, well known companies, service providers, and technology start-ups.

For each new technology, we cover four topics:

- WHAT IS GOING ON NOW?
- WHAT COULD THE FUTURE HOLD?
- WHAT ARE THE BENEFITS?
- WHAT BARRIERS MUST BE OVERCOME?
The core question facing supply chain professionals today is, how to achieve the next step improvement in customer service. Drone delivery may or may not be an answer. In December 2013, the CBS show *60 Minutes* highlighted the Amazon vision of a consumer package delivery. At the time, many thought it was a publicity stunt. Yet, Amazon continues to move ahead with patent filings for its multicopter delivery devices. Numerous media outlets have reported Amazon’s vision is a thirty-minute delivery by Amazon Prime Air. It likely would start in low-population rural areas. New Amazon stores in hundreds of locations could serve as drone airports. For residential delivery, substantial regulatory hurdles must be overcome. In fact, those are much more of a barrier than any technical challenges.

Drones can be operated commercially in a growing number of countries, and start-up projects exist around the world. For example, Amazon started Prime Air residential delivery for a few customers in December 2016 in Cambridge, United Kingdom. The trial delivered packages up to five pounds in thirty minutes or less (thirteen minutes in one trial). In that region of the UK, Amazon was granted approval to fly 400 feet high, beyond the line of sight (the drones have sense-and-avoid-technology to avoid collisions). Customers were required to place a small QR code sign on their lawn to serve as a landing pad for the drone. Such drone delivery concepts are evolving rapidly, and all of this is still very much in the experimental stage. Besides Amazon, one other large
retailer also is experimenting with drone delivery, and claims to have made many successful deliveries in the US in an FAA-sponsored experiment.

Other drone delivery concepts in the planning or pilot stages are:

**Drone delivery from a truck:** UPS and FedEx are considering a program where a drone will fly from a UPS/FedEx truck to deliver the last few miles. In a similar idea, Matternet (a maker of drone delivery systems) and Mercedes-Benz have a partnership to dock drones on a moving vehicle. The vehicle gets close and the drone flies from its roof to make the final delivery. The drone can also deliver while the truck continues to make its rounds.

**Drone landing:** Hosts of delivery methods are envisioned. One includes having an RFID tag on a locked mailbox that would be activated by the delivery drone. A DHL model delivers to a station in the neighborhood, and then sends the customer a text with a code to open the box. Another idea proposes dropping packages via a controlled parachute rather than landing the drone.

**Special applications:** UPS is testing drone delivery for emergency medical supplies. In a Google Project Wing test (initiated in 2012), the five-feet long, single wing drone hovers thousands of feet in the air and lowers packages to ground delivery robots. These drones would also have radio transponders that mark their location relative to other aircraft. Google reportedly is testing this concept in Australia. Such a drone could also be used for disaster relief scenarios once fully viable.

**Drone delivery from a store:** Drone startup Flirtey has successfully completed a number of delivery experiments. These include a Domino’s Pizza delivery, and a delivery from a 7-Eleven to a private residence in Reno, Nevada, in July 2016. Flirtey flew the drone a mile from the 7-Eleven location to the private home. According to 7-Eleven, the initial delivery included a chicken sandwich, donuts, coffee, candy, and Slurpees. The goods were packaged in two containers separately flown to the home. Once they arrived, each container was lowered to the ground and retrieved by the homeowners. Flirtey made seventy-seven drone deliveries from a 7-Eleven in December 2016.

The jury is still out on how rapidly this technology will roll out. It will be expensive, but some consumers appear to be willing to pay more for it whether directly or indirectly. However, will the average family be willing to pay for this convenience and speed? Will the decision be driven by the ‘coolness’ factor of having an Amazon delivery station at one’s house? One interviewee wondered if there would be Facebook postings stating, “The drone is on the way.” Clearly these questions are still up for debate.
The drone reportedly checks the entire one-million-square-foot Walmart facility in a day, as opposed to the month it takes for a human.

**Internal Supply Chain Usage:**
**Warehouse and Logistics Functions**

A number of companies are showcasing a wide range of drone applications for internal use within supply chain operations. Based on our research, drone usage in supply chain operations, as depicted in Figure 3, seems to be falling into the following categories:

**Inventory visibility:** A number of experiments use drones to track inventory in a warehouse. DroneScan and Corvus Robotics are two examples. In these applications, a drone navigates the warehouse and does a physical inventory by scanning barcodes or reading RFID tags. Several companies are also experimenting with image recognition technology to identify and track inventory. In a high profile example, Walmart used a drone to verify inventory in one of its large distribution centers (DCs). The drone reportedly checks the entire one-million-square-foot Walmart facility in a day, as opposed to the month it takes for a human. Full autonomy is the goal, and many believe we are on the verge of that now. This application improves operational efficiency, increases inventory accuracy, and helps provide better customer service.

**Inspection:** In 2016, BNSF Railway began using drones to inspect tracks, bridges, rail yards, and monitor air quality around rail yards. The company has 32,500 miles of track in its system, all of which needs to inspected multiple times per week. The drone application adds an extra layer of inspection without increasing congestion on or around the tracks. It captures data with cameras and sensors (e.g. laser profile sensors) to detect any changes, even as small as a quarter of an inch, that could lead to safety problems. The data are coupled with predictive analytics in an attempt to forecast potential problem areas.

BNSF Railway uses multicopter drones for short duration applications (i.e. less than forty minutes). The company also partners with the FAA on long-range heavier drones that would fly up to six hours for track inspections. These longer-range drones have an anticipated goal of identifying a quarter-inch separation in a track, even at night. These drones can also inspect areas that are difficult to get to, such as beneath tall bridges.

Akin to this idea of using drones for inspections, power companies anticipate using drones to inspect their power stations and high voltage lines. Another inspection application could be using drones to survey roofs, outside walls, and areas around distribution centers.

**Yard management:** Trailer yards sit at the intersection between transportation and warehousing and are often a forgotten link in a company’s supply chain.
Transportation assets spend a lot of time in trailer yards. One expert estimated that an asset spends up to 40 percent of its total transportation time sitting idle at either the point of origin or destination. That is why yard management systems are critical to tracking and optimally managing large amounts of transportation and inventory assets. Some organizations envision using drones to fly above trailer yards to track assets. Others argue that mounting a scanning device to a land-based vehicle would do just as well, with the exception of extremely congested yards.

PiNC specializes in yard management with its Advanced Yard Management Platform. Most of PiNC applications are land based, but they recognize that there are congested, hard-to-access areas which would be a perfect application for drone-based surveillance. Incidentally in another yard management application one company is experimenting with an automated guided vehicle (AGV) to retrieve a trailer from the yard and move it to the correct door.

**Service and repair:** A large equipment manufacturer plans to use drones to deliver spare parts to keep their large, expensive equipment running in remote areas. Beyond these applications, many companies are conducting research projects with drones. The commonly held belief is that great progress will be made in the development and application of affordable, autonomous drones in 2017. The key to widespread drone usage in the supply chain is the ability to have autonomous drones that take off, fly, land, and return without human intervention. Clearly, the use of drones in the supply chain is gaining a lot of momentum.

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**Figure 3**

**Drones in the Supply Chain**

- **Supply Chain Visibility**
  - Inventory Inspection & Movement
  - Facilities Inspection
  - Distributed Infrastructure Inspection
  - Yard Management

- **Customer Delivery**
  - Emergency Relief
  - From Truck
  - From DC
  - From Store
Customer Delivery

As e-commerce continues to advance, the need for a more viable solution to the problem of delivery in heavily congested and confined urban areas is of global importance. It is estimated that 5 billion people will live in urban areas by 2030. As a result, last mile delivery will become increasingly difficult in urban areas across many global locations. Some think that shipments would arrive at a hub location outside the city, with the last mile delivered via drone. Rural, hard-to-get-to areas are also a good option for drone delivery. The FAA projects the sale of commercial drones to quadruple from 600,000 this year to 2.7 million in 2020. The White House said unmanned aircraft could lead to $82 billion in economic growth by 2025, and support up to 100,000 jobs.

In the much more distant future, Amazon has patented an airborne fulfillment center (AFC). The concept is that the AFC would fly at high altitudes and deploy drones for customer delivery. One source called this the ‘Death Star’ for competition. This application would get around the problem of limited delivery range for drones, particularly if the mobile warehouse could fly to high demand areas, such as a big football game. Amazon has also patented the concept of a convoy of drones (i.e. megadrone) to carry heavier objects farther, and holds another patent that includes countermeasures to drone hacking.

Internal Supply Chain Drone Usage

Many believe that drones will become a major supply chain tool that goes well beyond residential delivery. In the near term, drones will likely be used increasingly for supply chain visibility. Again, the keys to large-scale adoption of drones in the supply chain will be (i) affordability, (ii) autonomous actions, and (iii) application versatility. A few applications of drone use in the supply chain include, but are not limited to:

Picking: Some envision the day of fully autonomous DCs, where swarms of drones could do picking and inventory movement. This would open up the vertical dimension, and make put away and picking on very high shelves possible in DCs with ultra-high ceilings.

Inventory management and yard management using fully autonomous drones: These drones will be self-learning and capable of acquiring the dimensions of warehouse and outside property, while adapting to obstructions.

Security and inspection: Autonomous drones will patrol the property eliminating a host of hardwired cameras periodically docking in a charging station.
Maintenance and repair: Some DCs are huge. To put it in perspective, a million-square-foot warehouse can hold twenty football fields. These DCs often have a lot of equipment and automation that require maintenance and repair. A repair technician could get drone delivery of parts in a fraction of the time it would require manually.

Transfers: This application would involve delivery of product or components from DC to DC or factory to DC. One company is moving support materials like dunnage, packaging, shrink-wrap, etc. from a remote location to shipping as needed, reducing congestion in the shipping area.

In the future, and even today, warehouses will have to be designed for the use of drones. Also, product packaging and barcodes will have to be developed for better visibility by drones.

WHAT ARE THE BENEFITS?

In an SCM World survey, one-third of all supply chain professionals said that drones are not only important, but potentially disruptive to the supply chain competitive balance. In a 2016 MHI survey, 59 percent said autonomous vehicles and drones are having some impact on their supply chain today, and 37 percent said they could lead to competitive advantage. The business case for drones differs depending on its application. Some benefits are listed below.

Breakthrough customer service: Rapid consumer delivery can give companies a competitive advantage and potentially increase market share. The average delivery time for a traditional package is 4.1 days. If it could be reduced to hours, would consumers buy more from the company? Or will this simply become ante to stay in the game, increasing cost for everyone? The business case for residential delivery still has a number of unknowns, but a sales increase likely stands at its core.

Cost: Drone applications could allow companies to avoid larger infrastructure investment in and around DCs and other supply chain assets and could help increase productivity. Internal drone applications tend to require less capital and/or fewer people.

Inventory/Customer Service: Drones will create more visibility in the supply chain. When supply chain visibility increases, there is the potential for inventory to decrease and customer service to increase. Some believe that drones will be used more for supply chain visibility than for consumer delivery. Proponents argue that drones will be safer than using traditional labor-intensive methods to see supply chain assets, which can involve reach trucks, forklifts, man-cages, and scissor-lifts.
WHAT BARRIERS MUST BE OVERCOME?

Drones have enormous potential but have some significant barriers to overcome. In the future, many drones will share the airspace with many other flying systems. A number of barriers will have to be overcome to get to that point, including:

**Battery life:** Drones will have weight limitations, an estimated fifty-five pounds including the payload. Advanced models will likely be fit with heavier additions to avoid obstacles and control autonomous flight, limiting the range over which they can operate. Amazon is exploring the use of docking stations on anything tall that has power running through it, such as street lights.

**Autonomy:** Fully autonomous flight, in all conditions, is the ultimate goal. Over 80 percent of the US population lives in urban areas where autonomous delivery will be a much greater challenge. DCs present challenges to autonomy in dealing with narrow aisles and their dynamic nature. It will likely take significant infrastructure for full autonomy in a warehouse. Drones will need sensors or even an indoor GPS with GPS beacons. Rapid progress is being made toward full autonomy, however. In a January 2017 episode, *60 Minutes* showed an incredible, fully autonomous outdoor military application with a swarm of 120 drones dropped from an F-35 fighter jet.

**Delivery:** There are many questions surrounding delivering to residences in a secure and safe manner. A number of options are being explored, but this will be complex, and the challenges will multiply depending on the location, such as delivery to apartment complexes.

**Global integration:** Regulations will vary widely from country to country.

**External conditions:** How well will drones be able to operate in bad weather or even in the dark? How often would they be grounded? Bad weather cities like Chicago could see drones grounded for a significant portion of the time. Challenges abound, including power lines, outdoor antennas, and indoor obstacles from large fans to dark areas.

**Business risk:** Although the FAA will not be involved in indoor flight, OSHA and insurance companies will be very interested. In outdoor applications such as yard management, a company could make a significant infrastructure investment for drones, only for the FAA to impose restrictions after the fact.
Safety: In a DC, many potentially unsafe devices, like forklifts, have to be managed. Drones are no different and will require a new set of safety protocols that are strictly adhered to, such as these requirements in one company:

- Never go under a drone
- Have warning lights or beeps on drones
- Always fly well above head height
- Never walk backwards while flying a drone

Cost: Drones can be expensive. Insurance costs may also increase. The ROI of drone implementations may be a challenge as well.

Visibility: Drones cannot necessarily see behind the first row in an inventory location or in dark areas. Barcodes or other identifiers may be obscured. Barcodes need to be visible, oriented in a standard way, and not damaged. RFID or image recognition may be part of the solution to this barrier.

Training: Significant training programs will need to be implemented for pilots until the drone application moves to fully autonomous.

Public concerns: These include privacy issues and perceived danger of a drone falling.

Regulatory issues: In addition to all of these barriers, many regulatory issues must be overcome, and these vary around the world. Some examples of regulatory issues are listed below:

- In August 2016, the US announced new and extensive regulations for commercial drone operations. Rule 107 states that drones must be no heavier than fifty-five pounds, fly no higher than 400 feet, be operated within line of sight in daylight hours, and flown by someone with a certificate. Substantial research is being made to find applications that can safely be done with less regulation. The new regulations also address speed restrictions and other operational limits, such as prohibiting flights over unprotected people.

- The FAA approved a number of ‘333 exemptions’ for new research-oriented drone applications, which will lead to a new series of regulations in the future.
The FAA published a document containing hundreds of pages of rules for an individual to be certified to operate drones. Drones are easy to crash and need a skilled pilot. One interviewee estimated that pilot training and certification would take a good two weeks. FAA regulations require pilots to keep an unmanned aircraft within visual line of sight. Operations are allowed during daylight and during twilight if the drone has anticollision lights. Minimum weather visibility must be three miles. The person actually flying a drone must be at least sixteen years old and have a remote pilot certificate, or be directly supervised by someone with such a certificate. The FAA is acting to address privacy considerations in this area.

The FAA will not hesitate to regulate drones that fly on private property.
Robotics

WHAT IS GOING ON NOW?

Robotics spans a broad spectrum. One could say that drones are aerial robots. Driverless vehicles are also robots in a sense. Here, we will focus more narrowly on robot usage in logistics operations. Robotics applications are inextricably linked to the digital side of innovation. With such a link, robots can become learning machines that are able to deal with dynamic changes in the environment in an efficient manner. The variety of robotics in some DCs is almost infinite. Nevertheless, advanced software—artificial intelligence embedded in microchips—is critical to making this connection.

Of the five technologies covered in this paper, many of those interviewed believe that robotics is the most advanced today for supply chain application. For nearly fifty years, firms have used automated storage and retrieval systems, automated guided vehicles (AGVs), and manufacturing robots. Though valuable, these systems hardwired a process into place. Some felt that it was instead best to streamline, eliminate waste, and apply Lean principles to a process before automating it. “Eliminate waste before you automate waste” has been the mantra from Lean manufacturing/lean supply chain advocates for many years. Back in the 1980s, it was estimated that General Motors spent as much on robotics as the entire market cap of Toyota. It was smart to be cautious about robot applications in the past, but robotics technology has experienced a monumental step-change in the last several years.

Robots are no longer stationary, blind, expensive, and unintelligent. In a 2016 MHI study, 51 percent of respondents said robotics is a disruptive technology. The automotive industry has always been the biggest market for robots, but widespread applications are expanding globally across many industries.
In recent years, online shopping has produced tens of thousands of new warehouse jobs, and the motivation to automate many warehouse processes has never been stronger. The US has nearly 900,000 warehouse workers, earning around $40,000 per year. In spite of robotics, recent demographic studies say that the nation will eventually see a shortage of such workers. In addition, labor costs are steadily increasing. For example, Governor Jerry Brown signed a law raising California’s minimum wage to $15 by 2022. Actions like this will accelerate the trend toward robots.

Robotic applications are also expanding globally at a rapid pace, even in low labor cost markets like China, and the rate of growth is exponential. Labor availability is the prime driver. High sales volumes for robots rapidly reduce prices. China is the largest market in the world for robots, and in 2015 bought more industrial robots than all of Europe. Germany, South Korea, and Japan lead the way in the ratio of installed robots to number of workers.

Some predict that many companies will soon have a robotics department and even a chief robotics officer responsible for defining the robotics strategy and coordinating implementation. Many major companies are partnering with robotics companies to develop robotic applications. Robots can take many forms in the supply chain. Here are some notable examples:

**AGV/ASRS:** Automatic guided vehicles (AGV) and automatic storage and retrieval (ASRS) applications have been around for many years in manufacturing and DCs. A large retailer believes that high-rise, automated, narrow-aisle, lights-out areas in the DC will be the wave of the future.

**Goods to person:** KIVA-type or goods-to-person robots help with order picking. (KIVA was renamed Amazon Robotics in 2015.) The robot scans a grid on the floor containing hundreds of bar codes, giving the location relative to other robots and directing the robot to take the product to the proper location. There are currently 45,000 KIVA bots and counting in Amazon DCs. In 2016 Amazon reportedly opened twenty-six fulfillment centers and had 361 DCs worldwide. These facilities employed over 300,000 people, a tremendous increase from the 30,000 personnel in 2011. Furthermore, it is believed that Amazon has plans to add 100,000 employees by mid-2018.

**Telepresence robots:** BEAM robotics can essentially allow someone to remotely conduct a tour and consult on problems/repairs, etc. It is essentially mobile Skype, or as some would call it a telepresence robot. Companies can justify these robots because they help to lower travel costs. The simple elimination of a few trips can potentially cover a $5,000 price tag.

**Follow-me robots:** Robots that move with people in the picking operation are sometimes referred to as follow-me robots. In this case, the human picker picks and the robot delivers. This is one example of a collaborative robot, or ‘co-bot.’
Locus Robotics and Fetch Robotics offer such mobile robots, and tout them as tools for e-commerce applications. One major durable goods manufacturer says the follow-me application speeds up picking operations. The cart follows, and when full, goes to shipping and another empty cart takes its place.

**Manufacturing:** Manufacturing is an integral part of the extended supply chain. Robotics started in manufacturing and are continuing to proliferate, with applications far too numerous to list.

There are multiple companies in the game. IAM Robotics makes autonomous picking robots that integrate with the WMS. Sensors allow it to detect and select items very accurately. Universal Robots (UR) makes easy-to-program co-bots. Clearpath has robots that are designed to move heavy pallets. They also develop follow-me robots.

Inexpensive and easy to program robots are emerging rapidly. Baxter-2012 and Sawyer-2015 from Rethink Robotics are inexpensive and easy to program. A non-technical person can program these robots by moving the robot’s arm. They can be used beside humans in repetitive operations. These robots sell for $30,000 versus hundreds of thousands of dollars in the past, and safely work alongside people. People comment that they love how Baxter’s facial expressions emulate a human face.

New applications come daily. There is the Lowebot, a robot in Lowe’s stores to help consumers. JDA is piloting a humanoid robot for a similar application. The robot has access to complete inventory information and can take payment and schedule delivery. It is essentially a tablet that speaks and interacts. It can take vague descriptions of needs from a consumer and lead them to a good solution. Other new applications are grocery and meal deliveries in Europe and mobile security robots to patrol the grounds of a facility. One company is using AGVs to take inventory in a DC and even on store floors.

*Figure 5*

**VARIETY OF ROBOTICS IN THE SUPPLY CHAIN**
WHAT COULD THE FUTURE HOLD?

Robots will take on many jobs currently executed by humans in the coming years. The incursion of robots will require more technical skills and less manual labor. The warehouse of the future will look very different. A futuristic distribution center may be designed to handle a swarm of robots instead of shifts of human workers. The DC will need advanced wi-fi capability and the flooring will have to be designed for convenient robot travel. Robots will self-learn, and software will be the most important component of the system. Efficient charging areas will be required to accommodate the next generation of batteries and their charging systems. The storage systems in DCs of the future may have to accommodate everything from narrow-aisle, high-rise ASRS systems to goods-to-person (KIVA-type) systems and collaborative robots.

Given their falling cost and ease of implementation, robots will be used in many ways in the supply chains of the future. Some examples are:

**Order picking**: The Amazon Challenge in 2015 offered a prize to the team who could design a robot to pick the most unknown items. They constructed a shelf with everyday items from Oreo cookies to spark plugs. In a similar event last year, the participants demonstrated major advances in their ability to pick. Robots have to deal with a vast array of product types. But with new sensing technology, it’s more and more possible, especially when linked to the cloud. With the cost of robotics going down, and wages going up, the business case becomes much easier. Many believe that robotic applications in distribution centers are at an inflection point and are about to grow exponentially.

**Collaborative order picking**: Collaborative order picking and collaborative co-packing/shipping applications will expand rapidly. Since collaborative robots work along side humans, they have to move slowly and carry a relatively small payload. But these limitations will gradually relax. The human-automation interface will become seamless. Robots will perform tasks that would be difficult for a human, like lifting heavier objects, or traveling longer distances.

One university is currently working to develop robotics technology where the robot reacts to a human without having to be instructed what to do next. Flexible and widely available services to rent robots will emerge and will be used widely during peak demand periods, such as at an e-commerce center during the holiday season.

**Robot consumer deliveries**: A number of experiments are taking place to use AGVs to deliver packages to consumer homes. In one example, a truck goes to a parking lot, and deploys AGVs to deliver the last mile. Some of the experts interviewed believe that robot delivery will greatly exceed drone delivery in the quest to find new ways to deliver to consumers fast.
WHAT ARE THE BENEFITS?

The benefits of robots are now obvious, with the business case calculation getting much easier. Today, robots are highly flexible and programmable. They can work in dynamically changing environments. Robots will not unionize, need a vacation, get sick, need medical or retirement plans, or even need a break. Other benefits include:

**Cost:** The explosion in robotic applications and rapidly increasing sales volumes are causing costs to come down. For instance, unit costs have dropped from several hundred thousand dollars to well under $50,000. Prices are 10 percent of what they were in the early 2000s. Robots can avoid human ergonomic issues that require expensive remediation. SKU placement will be simpler, requiring less profiling labor to rearrange the warehouse. Explosive e-commerce demands mean more ‘each’ picking, and a much greater demand for expensive and scarce labor. Robots stand ready to provide a lower cost solution, especially for an always-on supply chain.

**Flexibility:** Robots will be much easier to program and will not require highly trained technical personnel. They will be programed by learned movement or by touch screens. Flexible reprogramming will replace expensive retooling. The diversity of products that can be handled by a robot will grow rapidly. In the future, the robot will be connected to the cloud and will be able to look at an item and program itself on how best to pick and move it. Mobile robots can learn a dynamic and changing factory or DC environment. If something impedes its path, it will reroute itself. Battery charging will be autonomous. Robots can also act as data collectors and repositories creating an unprecedented analytics capability.

**Human resource benefits:** There are many HR issues that can be avoided in addition to pay and benefit costs. Recruiting and training expenses can be eliminated. Labor availability is a significant challenge in many areas of the US and globally, especially with shrinking populations in many parts of the industrialized world. More pickers will be needed due to the dot com revolution. Robotics will help to address a growing labor shortage in the western world.

**Global strategy:** Robotics will support the trend toward regional supply chains and near shoring since they will help neutralize the labor differences around the world. In an AlixPartners 2016 survey, 69 percent said near shoring is an opportunity they will explore.

**Safety:** Collaborative robots will allow humans and robots to work safely side-by-side. In the past, robots had to be put in cages. Robots can eliminate dangerous, dirty, and demoralizing work for humans.

Robots will not unionize, need a vacation, get sick, need medical or retirement plans, or even need a break.
WHAT BARRIERS MUST BE OVERCOME?

Even though applications are expanding rapidly, there is still much work to do. Robots will need to improve in the following areas:

**Picking flexibility:** There is a myriad of product variety, and the challenge to pick generic items is daunting. Today robots are good at rigid boxes and bottles. Humans excel at deformable items like apparel. For many tasks, only a human possesses enough hand-eye coordination. Walmart’s website offers 20 million SKUs, and that’s a lot of variety. But these limitations will gradually disappear.

**Speed of operation:** A collaborative robot can be safe, but to achieve safety it must sacrifice speed.

**Range of application:** Yes, they can operate around the clock, but often humans have to man a front- and back-end. The new inexpensive collaborative robots have a small lift capacity (five to ten pounds). Therefore they must be applied to the right product. There is still a relatively narrow band of application for such robots.

**Cost:** Although costs have come down, they still need to fall farther for wider adoption. A large amount of capital is still required for large-scale rollout. Furthermore, robots require people and other associated costs on the front- and back-end as noted above. Technical resources needed for maintenance and support are another significant cost area. Companies will have to invest in more high tech maintenance resources or outsource the maintenance.

**Psychological barriers:** The above barriers will be overcome. But for some there will remain an inherent, fear-driven mentality that robots can hurt workers or take their jobs for some time.
Wearable Technology/Smart Glasses

Wearable technology is a broad and expanding topic. A wearable can be on your wrist, in your ear, over your eye, or embedded in clothing. Wearables range from smart glasses to personal sensors that can detect fatigue or abnormal changes in vital signs. Wearables, and particularly smart glasses, can fall into several categories: virtual reality (VR), augmented reality (AR), and mixed reality (MR). AR and MR maintain an existing physical reality, but add a digital element to create a value-added mix of real and virtual, as opposed to VR, which completely immerses the user in a computer-generated and simulated environment. More specifically, AR takes advantage of your natural view of physical objects and sounds around you and enhances them with an overlay of digital information (e.g. text, simulated screens), while enabling the reflection of both synthetic and natural light off the physical objects. MR, on the other hand, brings virtual and real worlds together to create new environments. In these newly created environments...
environments, digital/superimposed objects and sounds and physical/actual objects and sounds, as well as their data, coexist and interact with one another. In addition to smart glasses, smart phone, and tablet applications can also superimpose virtual information over a real world environment.

WHAT IS GOING ON NOW?

Smart vision has the opportunity to make a major impact on the supply chain. But, the applications will need to improve and create a compelling business case to be feasible. Some supply chain applications are emerging such as:

**Microsoft Hololens:** an MR product being used for a range of applications in the supply chain, especially for training in hazardous environments. For example, it can project holograms of unsafe conditions in an existing DC. A person wearing the headset can walk through the DC and identify safety problems. These headsets cost in the neighborhood of $3,000.

**Google Glass, Vuzix Smart Glasses, Epson, Apple:** all examples of companies producing or planning to produce lightweight durable AR headsets focused on industrial applications. Google Glass initially focused on the consumer market, but is now concentrating on industrial applications. These companies will provide a wide range of industry solutions including applications in manufacturing, quality assurance, remote support, healthcare, training, utility/field service, and warehouse logistics. The Apple application is targeted for 2018, and will connect to an iPhone for processing. Such applications are being tested by DHL and are being piloted in the US and Europe.

**DC pick, pack, and ship applications:** DC applications are currently very limited and experimental, but with hands-free AR solutions such as smart glasses, warehouse pickers can theoretically finish tasks more quickly and efficiently while reducing mistakes. Such applications being tested by DHL and are being piloted in the US and Europe. The smart glasses can improve the process of manual order picking, incoming/outgoing goods, or sorting and packing of goods, as well as inventory and deficiencies.

WHAT COULD THE FUTURE HOLD?

Smart glasses have the potential to positively impact the warehouse of the future in a number of ways. The technology will need to have multiuse capability, and make performance of repetitive tasks more efficient and accurate. Smart glasses must be able to visually separate the right products in a complex
picking process. And the unit cost will need to be reduced drastically for widespread adoption. Some examples of future applications follow:

**DC customization applications:** Smart glasses may be used to enhance many DC processes. They could provide faster ramp-ups and improved quality and productivity by providing relevant information, confirmations, and documentation directly to workers’ eyes.

**Work optimization through experience sharing:** How to stack a pallet is an experienced-based skill. If an optimal technique can be captured, smart glasses could guide other workers through the learning process. There can be ‘head’s up’ displays that alert users to a better way of doing any number of tasks, or how to avoid unsafe conditions. Virtual digital assistants like Siri, Alexa, and Cortana can be added to help answer questions with a visual demonstration. A host of work instructions can be displayed for the user.

**Service and repair:** A repair technician can bring up instructions on their smart glasses and can also connect with an off-site expert.

**Order picking optimization:** Smart glasses could show the shortest, safest path to the next pick, and could highlight the item to be picked, (e.g. pick to glow). Scanners will be integrated into the glasses. A warehouse management system interface will be required. An example of this is Vuzix integration with SAP’s WMS. Some envision linking two wearable technologies: smart glasses and smart watches having multiple forms of data available and as well input options.

**Engineering design:** Smart glasses that create virtual environments will be useful for engineering applications. A remote design engineer can see activity in real time on the shop floor. An engineer can virtually walk through a new DC layout and modify it.

**Gamification of the workplace:** To motivate Millennials and future generations, some visualize a workplace where gamification through smart glasses will have a positive impact. Smart glasses could display information to promote competition, and/or show progress toward a goal. KPIs could be displayed. The smart glasses could display motivational messages once certain goals are achieved. For example, “You have received an award…parking, cash, etc.” Of course, some workers, particularly older generations, might find all of this horrifying. Some are not motivated by competition and would fear bullying and humiliation.

**Temporary workforce management:** Smart glasses will be able to provide step-by-step instructions for complex tasks or temporary workers. Using this technology could facilitate training temporary workers more quickly and easily. This application of the technology could be especially useful when large numbers of such personnel are hired for huge holiday and e-commerce volume spikes.

*Some visualize a workplace where gamification through smart glasses will have a positive impact.*
Other wearable technology: Sensors may be put in clothing to judge fatigue and motivate safety. Other wearables could monitor vital signs (e.g. employee biometrics), warn of movement into a dangerous area, or even be able to shut down a forklift or robot if necessary. 3-D holographic image generation will be used to allow people in different locations to work simultaneously on the same problem.

WHAT ARE THE BENEFITS?

Order picking is one of the most obvious applications of smart glasses and ideally will improve productivity and accuracy. Moving forward, the business case needs to consider the cost and benefits of smart glasses versus other picking technologies, such as voice picking. Some potential advantages of smart glasses over voice picking are:

- Smart glasses can highlight an item once the worker approaches it, making it faster than voice picking for location. The picker does not have to read back the check digit. The pick can be confirmed through scanning by the glasses. All of this would increase speed and accuracy, but perhaps only marginally over voice picking systems.

- The glasses can guide a picker along the shortest path through the DC using an internal built-in GPS location system that could also be useful for internal drones and robots.

- Smart glasses will have a voice component and a vision component to enhance speed and accuracy. Gesture control could eliminate the need to a voice response.

WHAT BARRIERS MUST BE OVERCOME?

Recognizing that many companies will not want to be on the leading edge, smart glasses and other wearable technologies have barriers that must be overcome to achieve widespread adoption. These barriers include:

Wearability: Smart glasses must be comfortable to wear for eight-hour shifts. Designs will need to become lighter and smaller. They will have to be able to be worn over one’s personal, prescription glasses. Some day this problem may be solved with a smart contact lens. One large company said they tested smart glasses in a DC, but workers did not like them. Associates felt the smart glasses were unsafe and obstructed their view of obstacles. Others reported disorientation, headaches, and vertigo.
Privacy: Both personal and corporate privacy concerns exist if information and communication capabilities (e.g. a computer, camera, recording device) is integrated into eyewear. From a personal privacy perspective employees tend to feel that big brother is watching. From a corporate privacy perspective, there is concern among executives about accidental or intentional disclosure of trade secrets and intellectual property. Terms of use and privacy agreements between vendor, company, and employee need to be transparent and addressed.

Battery life and the wi-fi environment: There will be battery life and wi-fi network challenges. The wi-fi system will have to support vastly higher data traffic than any radio frequency application today.

Business case: Smart glasses application will require significant capital and will need a clear ROI. This in turn will make the business case more challenging. The incremental benefits over the current picking system must justify the investment. Trying to tease out the value proposition of smart glasses will require a comprehensive impact assessment across the organization. Operational expenditures in one department may be increased by the infrastructure to support smart glasses use in another department. It will be difficult or impossible for 3PLs with shorter contracts (five years of less) to make upfront investments to support this technology. Of course, a 3PL would be a perfect partner to use to implement this and other new technologies as long as a win-win, gain-sharing agreement can be reached.

Security: Given the relatively high cost of smart glasses, and their use potential beyond the walls of the company, the ease of theft is of great concern. This barrier becomes more challenging as devices start to resemble traditional eyewear and have a smaller form factor.

Figure 7

BARRIERS TO SMART GLASSES IN THE SUPPLY CHAIN
Additive Manufacturing/3-D Printing

3-D printing has been viable for many years. Starting with an object represented in digital form, the process applies material in layers in an additive manner, unlike the old CNC technology that removed material. Some supply chain professionals predict 3-D will eventually rival the impact of Henry Ford’s assembly line. Other experts we talked with think the applications will be very, even extremely, limited in the near future.

Thirty years ago, a process called stereo lithography was patented. Iterative improvements occurred until 2009. That is when a key patent fell into the public domain, and 3-D printing became a mainstream idea. Applications expanded rapidly and uses such as 3-D printed body parts began making headlines. AT Kearney forecasts that 3-D printing will grow to a $17 billion industry by 2020, with a compound annual growth rate of over 14 percent. Gartner estimates that global shipments of 3-D printers will approach 7 million units by 2020; that’s a remarkable increase from 450,000 units in 2016.

3-D is used today in many companies for rapid prototyping. But its applications within supply chains are advancing well beyond this daily. Some believe that service parts are the next big application. Futurists envision a day, albeit in the very distant future, when consumers buy products online that are then downloaded and printed in their home. Some believe this application of 3-D printing will eliminate the supply chain. Others are not quite as willing to say that. They do, however, believe some forms of disintermediation are possible and that could result in supply networks with a different look than we see today.

The question is how fast will this technology broadly impact the supply chain? Will it be a quick game changer, or will it more gradually find its way to a broad scale application? The general consensus tends to be the latter.
WHAT IS GOING ON NOW?

3-D printing technology continues to advance. Current applications generally have some of the following characteristics:

- Low volume
- Complex geometries for assembly
- Need for fast consumer response
- Need for customization

Some specific applications include:

**Running shoes:** Nike, Adidas, and New Balance are experimenting with printing soles designed specifically for the user. The customer runs on a treadmill, and the custom insole is printed in the back room.

**Dental crowns:** In the past, when a patient needed a crown, the dentist took a mold impression and the customer came back a week later. With 3-D printing, the crown is made on the spot.

**Rapid prototyping:** for new parts or products.

**Customized body parts:** (e.g. knees, hips) Stryker has a 3-D printing innovation center and is investing heavily in a 3-D manufacturing operation in Ireland.

**Promotion customization:** Items can be customized for individuals and used in sales/marketing promotions, from trinkets to chocolate treats.

**Hobby use:** UPS has about 100 stores with 3-D printers and offer 3-D printing as a service. Staples is also competing in this space. Shapeways.com is another example of an available 3-D printing service for consumers.

**Repair parts:** One manufacturer we talked to reports printing a large number of repair parts as needed. In December of 2014, NASA sent a digital file to the space station for a much-needed wrench that was subsequently made with a 3-D printer. Although this application has a cool factor, repair part printing is far from widespread today.

**Low volume/high value components:** GE Aeronautics recently used 3-D printing to manufacture fuel nozzles for jets. This reportedly replaced forty components shipped in from suppliers.

**Metal additive manufacturing:** In late 2016, GE acquired a controlling stake in Concept Laser, a German company specializing in metal additive manufacturing. They design applications in the aerospace, medical, dental, automotive, and jewelry industries, and claim to be hitting an inflection point in demand with metal 3-D printing.
Experimentation: Experiments are underway in hundreds of companies. For example, TNT Germany has established a number of 3-D printing stations around Germany to investigate how to utilize this technology. SAP is partnering with a number of companies, especially UPS, in developing distributed manufacturing capability to bring scalable 3-D printing applications to industry.

WHAT COULD THE FUTURE HOLD?

It will be fascinating to see how this technology evolves, and its evolution will be highly dependent on the speed of operation in the 3-D process, the materials that can be used, and the overall cost. If significant progress can be made on those challenges, industry could be on the eve of a supply chain revolution. How fast will we be able to go from prototyping and printing low volume, customized, and replacement parts to higher volume, mass customization manufacturing? The short answer is, “We don’t know.” A brief reason for our ambiguity is that it depends on the movement of the three points mentioned above (i.e. speed, materials, cost) and the inflection point of the three.

Some applications of 3-D printing that are expected to be widely implemented in the future are:

Print in route: Amazon has a patent for a mobile 3-D printer. The idea is to avoid inventory and print a customer’s order in route. As reported recently in the press, TNT Express, Amazon, FedEx and others are evaluating 3D printing delivery vehicles.

Widespread use for repair parts: Repair parts will be carried in digital form and metal parts and other materials will be printed as needed. This will avoid a huge amount of very slow-moving inventory that is literally held for decades in many companies today.

Higher volume customized manufacturing: A swarm of 3-D robotic printing spiders comes to mind. Multiple robots will work together to build an object. Maybe even hundreds of them will someday build a car.

Mass personalization: Discussed for decades, mass customization to the specific needs of a consumer will become a reality.

Supply chain disintermediation: The elimination of certain parts of the supply chain will become feasible in some industries. Some component suppliers will disappear. Supply chains of the future will look very different. Final manufacturing sites will be located much closer to the consumer.
Regional manufacturing: This technology will support regional manufacturing and the return to local manufacturing. A transition will take place from make-to-stock in low cost locations to make-on-demand close to the final customer.

4-D printing: This very futuristic concept is the ability for a 3-D object to transform with the addition of stimuli, such as water, light, and/or electricity. For example, a flat item could be printed and shipped. Then the addition of a stimulus would cause the item to transform into its final shape. Some experts argue this will lead to future advancements in the use of active origami, where flat sheets automatically fold into a complicated 3D component. There have been some experimental examples of this where scientists have been able to demonstrate light weight material supporting exponentially more weight in its active origami state than it could support in its natural state.

Supply chain elimination: This ultra-futuristic concept may not be in the lifetime of anyone reading this white paper. The idea is to order a wide variety of products, have them delivered digitally, and then printed in one’s home, which would totally eliminate the supply chain.

WHAT ARE THE BENEFITS?

3-D printing promises incredible benefits if it can be adopted widely. The benefits fall into the following categories.

Faster customer service: This technology should provide faster response to demand with fewer out-of-stocks.

More customized product: 3-D printing may be the ultimate answer to the ubiquitous problem suffered by almost all companies, namely too many SKUs. This technology could create a utopian supply chain world of nearly infinite SKUs at no additional cost.

Lower inventory: It will be possible to store 3-D files rather than the actual inventory. Smaller inventories also translate into less need for warehousing.

Less transportation: It will be possible to compress network flows and disintermediate some parts of the supply chain.

Lower cost product: 3-D printing offers the promise of product redesigns using drastically fewer component parts and fewer suppliers. It could, for example, eliminate the hefty investment required for expensive dies and molds.
3-D printing

suffers from slow speeds, high cost, possible low quality precision output, limited materials, and lack of widespread technical expertise.

What barriers must be overcome?

The experts we spoke with understand that although 3-D printing has an important place today, there are many barriers to widespread adoption. A great deal of research is being done to overcome those barriers, but they are daunting. 3-D printing suffers from slow speeds, high cost, possible low quality precision output (requiring substantial post processing), very limited materials, and lack of widespread technical expertise. 3-D printing with metals, for example, requires a very expensive printer and is a slow process. In addition, parts will have to be designed for 3-D printing upfront, instead determining in a post hoc manner how to print an item. If these limitations can be overcome, it will truly be the third industrial revolution.
Driverless Vehicles

Driverless vehicles became feasible over a decade ago and have continued to make major advances since. In mid-October 2015, it was reported that Mercedes-Benz introduced a production driverless truck. The driverless systems use short and longer-range radar and a camera for detecting lanes and markings. In one application, the driver simply presses a blue button, engages the highway pilot, and sits back and relaxes. The National Highway Traffic Safety Administration has defined several levels of driverless vehicles:

- **Level 0** is where the driver is fully and actively engaged in driving the vehicle (i.e. does everything)
- **Levels 1-2**: The vehicle can sometimes assist the driver in conducting or actually take over some functions (e.g. steering, acceleration).
- **Level 3**: The vehicle can conduct some functions pertaining to driving and monitor the driving environment, but the driver must be present and ready to resume full control when prompted by the vehicle.
- **Level 4**: The vehicle is fully autonomous with limitations. It is similar to Level 3, with the exception that the driver does not need to take back control from the automated system. There are limitations with respect to the environments and conditions under which the automated system can be engaged.
- **Level 5**: The vehicle is fully autonomous under all conditions, even extreme conditions.
WHAT IS GOING ON NOW?

Remarkable applications have proven the feasibility of driverless technology. Some recent developments include:

**Actual deliveries:** An Uber-Otto/Anheuser Busch beer delivery occurred on October 16, 2016, from the Ft. Collins brewery to Colorado Springs, a 120-mile journey. For the majority of the trip, the driver left his seat and observed from the sleeper cabin. Uber bought Otto in mid-2016 for $680 million. Uber’s Otto (UO) is not to be confused with the brand name OTTO used by Clearpath for some of its robotic applications. The UO system involves a $30,000 retrofit, including several light detection and ranging (LiDAR) units and a high precision camera above the windshield. It offers true Level 4 autonomy. Drivers become harbor pilots, who just bring the ship into port.

**State regulations:** A rapidly increasing number of states allow self-driving vehicles under some conditions. Nevada was the first in 2011. California, Michigan, Florida, North Dakota, Tennessee, Utah, Washington DC, and Arizona have followed recently. Pennsylvania, Ohio, and Michigan have agreed to work together as part of a Smart Belt Coalition dedicated to initiatives involving driverless vehicles.

**Many companies are in the game:** Amazon has been granted a patent for a roadway management system capable of communicating with autonomous vehicles for driving assistance. TomTom, a leading provider of navigation products, acquired an autonomous driverless German startup company, Autonomos. Tesla, GM, Fiat-Chrysler, and many others are spending billions on driverless vehicles. In the Mercedes-Benz Future Truck 2025 project, once a truck reaches 50 mph on the highway, the driver activates an autopilot. Cruise automation bought by GM can outfit a truck for driverless operation. Apple and Google are also developing the technology, some in partnership with automotive manufacturers. FedEx is partnering with several companies and experimenting with ways to link trucks into caravan groups or platoons.

**Global experiments:** Driverless truck experiments are underway in several parts of the world. For example, a truck platooning system, in which groups of two to three smart trucks travel together communicating wirelessly, was introduced in Rotterdam in April 2016. In another example in the UK, autonomous vehicles by Nissan are being tested on the streets of London. The Nissan autonomous model is targeted for release in 2020.

**Driverless in DCs:** Automated guided vehicles and forklifts in factories and DCs no longer have to follow fixed paths. They can adapt to barriers that dynamically come into their path.
WHAT COULD THE FUTURE HOLD?

Driverless trucks may be a lot closer to reality than people think. Legal issues and government regulations will be the main barriers. Driverless trucks will first appear on the interstates with local drivers doing the first mile and last mile pickups. Local pickup and delivery steps are the most visionary aspect of driverless trucking. Platooning should go live within five years on some stretches of road, involving an active driver in the lead truck, followed by other trucks without drivers.

Technology will greatly outpace adoption. The forecasts for widespread implementation vary widely (e.g. from five to twenty-five years) but few doubt its viability. Many are betting that driver-in-the-cab implementations will be widespread by 2020. In the meantime, driverless technology is advancing rapidly. Reports are that Toyota and Nissan expect to have autonomous vehicles by 2020, and Tesla is planning for autonomous driving by 2023. Uber projects a significant driverless fleet by 2030.

The White House Council of Economic Advisors says that the proliferation of self-driving trucks threatens the jobs of nearly 1.7 million commercial truck drivers.

WHAT ARE THE BENEFITS?

The benefits of driverless trucks are obvious, and those benefits will drive adoption at a rate faster than many think. Those benefits include:

**Productivity:** There will likely be a return on investment even before fully autonomous trucks hit the highway. Once drivers can relax on the road in a Stage 4-5 environment, the Hours of Service (HOS) regulations are expected to be relaxed. A driver can be resting and moving at the same time. With HOS regulations today, trucks are only 45 percent utilized, since drivers can drive only eleven of twenty-four hours. It will be interesting to see if future regulations address increased autonomous driving by making a distinction between total HOS and active HOS.

**Fuel savings:** The Department of Transportation estimates that several trucks drafting via driverless convoys will save up to 7-10 percent of fuel. A test by Auburn University showed a fuel savings of 5-10 percent.

**Safety:** The legal cost of a crash can be astronomical, to say nothing of the human cost. Ninety-four percent of auto crashes are due to human error and
result in more than 30,000 deaths annually. Insurance rates should come down over time as driverless trucks will be safer.

**Driver shortage:** There are 3.5 million truck drivers in the US to date. However, the American Trucking Association estimates the driver shortage to be more than 50,000 drivers today and triple by 2024.

**Faster customer delivery and lower inventory levels:** If there is less time in transit due to a relaxation of the HOS rules, inventory will fall for a couple of reasons. One, there will be smaller amount of inventory actually in transit. Two, there will also be less need for safety stock as cycle times shrink.

**More efficient flow of goods:** Driverless trucks will impact network designs, and the number and location of DCs. Faster delivery times made possible by always-moving trucks would mean fewer DCs needed to provide the same level of customer service.

**WHAT BARRIERS MUST BE OVERCOME?**

The technology is far ahead of regulatory environment and social acceptance. There are a number of barriers that must be overcome for driverless trucks to become widespread in the United States. Those include:

**Infrastructure:** Some infrastructure upgrades may be needed, such as better signage, improved highway-to-vehicle communications systems, and more efficient refueling.

**Reliability and safety:** Cyber security, reliability, and maintenance will all be significant issues to address as this technology expands.

**Cost:** Although the cost of retrofitting existing vehicles with autonomous capabilities is slowly decreasing, such an endeavor is still expensive. There is still an unknown with respect to insurance, despite the fact that experts believe driverless trucks will be safer.

**Social acceptance:** This will take some getting used to. Some report that being in a driverless vehicle or driving next to one is very unsettling. A single accident could send the public off the deep end. It is not difficult to envision a lose-lose situation in which a driverless truck, which will likely rely on rules-based technology, faces a moral dilemma such as when the brakes on a truck fail on a downhill slope. If it veers to the right, it will go off a cliff. If it veers to the left, it will strike an on-coming car. If it stays in its lane, it will strike a slow moving car in front of it.

*Driverless trucks may be a lot closer to reality than people think.*
**Regulatory environment:** How fast will the regulatory environment allow for driverless trucks? The Department of Transportation released the Federal Automated Vehicles Policy, a policy for self-driving vehicles, in September 20, 2016. The policy includes detailed assessment guidelines for the design, testing, and deployment of these vehicles.

**Technology:** The technology needs to advance. Today trucks do very well at holding their lane and accelerating and decelerating smoothly. The technology to do more is advancing rapidly. The phases will be hold the lane, move from lane to lane, move from exit to exit, and travel from dock to dock. Some examples of challenges are wide turns that violate a lane, the absence of markings in a trailer yard, or bad weather conditions.
Recommended Process for Pursuing Innovation

Pursuing new innovative ideas is a complicated process with a wide range of considerations. Nevertheless, hosts of companies including manufacturing, retail, logistics service providers, software providers, and technology-driven service providers are exploring these new technologies and attempting to understand the potential benefits they can deliver.

Some have gone through the extent of formally establishing innovation centers or labs, such as the Kenco Innovation Labs, where talented people are removed from the daily operations to explore these technologies together with the device makers and customers. Others partner with academic institutions or technology vendors, such as JDA Software’s Innovation Lab (JDA Labs) where they explore the convergence of physical and digital innovations and turn them into standardized solutions.

We strongly recommend that each company develop an innovation strategy. We also recommend that they build a roadmap to explore these technologies and anticipate how relevant they are to your business now and in the future.
In the book, *Supply Chain Transformation*, we proposed nine steps that a company could use to develop its innovation strategy. That nine-step process is:

1. Assess your customer needs (All innovation should ultimately focus on supporting the drive to customer satisfaction).

2. With outside help, evaluate your internal processes and capabilities to manage the new wave of supply chain innovation.

3. Survey the landscape of supply chain innovation megatrends, and then take a first pass at assessing which ones may be most relevant to you.

4. Benchmark competition and determine how they are addressing supply chain innovation.

5. Evaluate the new supply chain technologies in depth, and perhaps do a preliminary estimate of return on investment.

6. Assess the risk to your supply chain and to your company posed by these new technologies.

7. With the above information, determine what new capabilities you need to develop and then prioritize them.

8. Assess your organizational structure and in detail evaluate your human resources to make sure you have the right skill sets in place to get to the next level.

9. Develop a business case; get buy-in; develop detailed project plans; implement.
Conclusion

As noted at the beginning of this paper, never before have there been so many new technologies that could impact the supply chain. They have the potential to disrupt the competitive balance among companies. The challenge ahead is daunting. But as we link these new technologies with sophisticated digital interfaces, it will be an exciting time, and a great time to be in this profession we call supply chain.

In this white paper, we tried to present a balanced view of several new innovative concepts that could greatly impact the physical supply chain. All of them have the potential to be revolutionary. There are huge risks and enormous rewards associated with the coming change. It is imperative that companies keep up. Try to understand what your competitors are doing. Launch a few pilots. Attend conferences and trade shows. You will need to be more vigilant than ever before. The landscape will shift and probably shift quickly. Your company will have to understand and stay current on the emerging developments in three areas:

- The digital side of innovation
- The physical side of innovation
- The software side of innovation.

We recommend at a minimum that you put in place the resources necessary to stay close to all of the unprecedented developments that are shaping our field. No doubt there will be other new concepts that will emerge that we do not yet know about. The real message is this: realize that we are now in a new era, an era of unprecedented advances. Business as usual will be fatal. But unlimited opportunities await those who embrace this coming wave of change.
A FINAL NOTE
We hope you have found the material in this white paper helpful and useful. We at the University of Tennessee’s Haslam College of Business are committed to translating our top-ranked position in academic research into information useful for practitioners. We believe the real world of industry is our laboratory. It’s why we have the largest Supply Chain Forum in the academic world, with over sixty sponsoring companies. We are always looking for industry partners to assist us in this journey. Let us know if you are interested in being one of our valued partners.

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