Make Global Supply Chains More Effective with Internet of Things

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RESEARCH PAPER

MALAYSIA INSTITUTE FOR
SUPPLY CHAIN INNOVATION

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IN BRIEF

This report examines how companies might use the Internet of Things (IoT) to make global supply chains more effective. Using the framework in this report, organizations can envision how IoT could be used to improve supply chains, with application of the framework to opportunities in the semiconductor, automotive, and ecommerce industries. Finally, the report presents challenges that must be addressed to realize IoT's promise for improving the effectiveness of global supply chains.

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Many believe the Internet of Things (IoT) will radically transform global value chains. IoT, widely considered a central pillar of the Fourth Industrial Revolution (i.e., "Industry 4.0"), coincides with another seismic shift for business: the emergence of developing countries as growth engines of the global economy.

In its agenda-setting 2015 report, The World Economic Forum noted that IoT for industry is still in its infancy. "Many important questions remain, including how it will impact existing industries, value chains, business models and workforces, and what actions business and government leaders need to take now to ensure long-term success."[1]

Yet, some industries are beginning to apply IoT to business:

- A Smart Cities solution to facilitate parking uses sensors buried in parking spots to detect parked vehicles. The information is broadcast so that those with the service app on their mobile devices can find vacant parking spots remotely.[2]
- A waste management solution uses containers equipped with sensors to monitor the fill level and transmit the information wirelessly. A pilot study at the Municipality of Rotterdam showed that this system could reduce the city's waste collection days by at least 20 percent by routing garbage trucks dynamically to visit the containers as they are filled to the optimum level.[3]
- A Tire Pressure Monitoring System embeds sensors in tires to measure pressure, temperature, speed, etc., and transmit the information in real time. The system is especially useful for monitoring the tires of mining vehicles, where an hour of equipment downtime can cost thousands of dollars. Sensors alert equipment operators of overheating, under-inflation, and more via SMS and email so they can take corrective actions and initiate predictive maintenance.[4]

IoT, defined

World Economic Forum[5] defines IoT as "a network of physical objects that contain embedded technology to communicate and sense or interact with their internal states or the external environment." Objects include mobile devices and "consumer products, durable goods, cars and trucks, industrial and utility components, sensors, and other everyday objects" that are "combined with internet connectivity and powerful data analytic capabilities."

How well do manufacturers understand IoT today? [6]

MPI Group surveyed 350 U.S. manufacturers in 2015 and found:

- 67% of companies had, at best, limited companywide understanding of IoT.
- ~50% said their current information technology needed either significant upgrades or a major overhaul to enable machine-to-machine or machine-to-enterprise communication.

These forays into IoT for business are only the beginning. Potential IoT applications for all kinds of businesses have been proposed, discussed, and debated for some time. Now, as experiments have taken place around the world, technology has advanced dramatically. IoT is quickly moving from the realm of theory to reality.

This report examines how IoT might also be applied to global supply chains in three industries to make them more effective. The report will:

- Highlight how IoT differs from current information technology tools used to manage supply chains and offer a new framework that can be used to envision IoT applications for global supply chains;
- Apply the framework to global semiconductor, automotive, and ecommerce supply chains to show how IoT might be applied in novel ways;
- Explore potential challenges to implementing IoT capabilities in global supply chains.

Logistics professionals may find it useful to review the examples from the profiled industries and use the framework to envision IoT supply chain innovations for their own industries.

A FRAMEWORK FOR ENVISIONING IOT FOR GLOBAL SUPPLY CHAINS

One early study suggested that IoT applications could help manage business processes through information and analysis and automation and control; another study saw that IoT might improve operational efficiency, aid in the emergence of the outcome economy,[7] connect ecosystems, and enable human-machine collaboration.[8] While a good starting point, these studies do not recognize how IoT's potential could transform the way shippers think about supply chains.

What makes IoT revolutionary is that *it creates its own information ecosystem*, quite distinct from the information technology tools being used today. IoT can collect a vast variety of data types, share it quickly across multiple trading partners, and integrate many sources of information in innovative ways to enable better decision making.

The following framework[9] was created to help companies envision an infinite number of ways they might use IoT to improve global supply chain performance by changing one or more of the three areas in the framework. For example, a manufacturer could fit equipment with sensors to gather various parameters related to the equipment's functioning and transmit that data to the manufacturer. They could track the data and use predictive analytics to automatically schedule maintenance. This IoT capability could even engender a new business model, enabling the manufacturer to lease the equipment to a fabricator and guarantee a specific level of uptime. This opportunity could be enabled even for older equipment by installing IoT retrofitting kits.[10]

This report shows how the framework can be applied to three industries—semiconductors, automotive, and ecommerce. It suggests ideas for using IoT to improve global supply chains.

FIGURE 1

Framework for envisioning implications of IoT

IOT FOR SEMICONDUCTOR SUPPLY CHAINS

The semiconductor device manufacturing industry is global, with a strong presence in Asia. The industry produces devices—transistors, microprocessors, systems-on-chips, etc.—that are used in electronics and telecommunications equipment. The key supplier and customer industries of semiconductor device makers are also global, with a strong Asia presence.

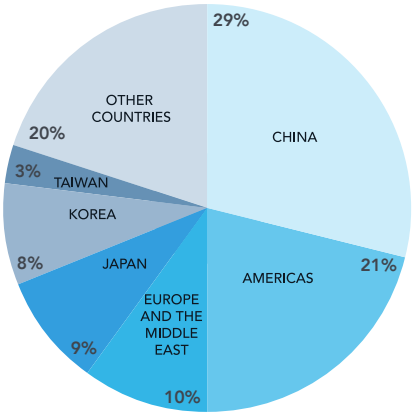
One of the most obvious implications of the emergence of IoT for this industry is the increase in demand for semiconductor devices, which are embedded into new types of electronic and computation products. Supply chains will have to accommodate the growing demand for semiconductor devices, equipment, wafers, and supplies, as well as the raw materials and capital equipment that are required to develop devices.

FIGURE 2

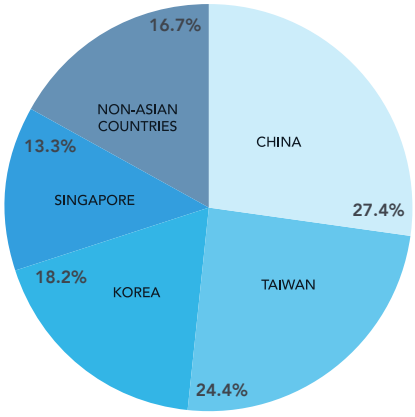
Global semiconductor industry

$339.8B (USD) in 2016[12]

Largest Markets
(percent of global demand)[13]



U.S.-produced semiconductor equipment sent to Asian countries in 2016 (estimated)[14]



Attributes of semiconductor supply chains

Manufacturing is shifting to North Asia. Historically, U.S. semiconductor manufacturers tended to focus on technologically sophisticated high-margin products (e.g., processors and NAND memory), and Chinese manufacturers produced lower-tech margin products. From 2010 to 2015, demand grew for low-tech products. The U.S. share of the overall industry decreased by 9 percent annually, and China's share grew by 7 percent to $63.1B (USD).[15] This trend of shifting production towards Asia is likely to continue, with Chinese device manufacturing expected to grow to $76.5B (USD) by 2020.[16] During the same time, buyers of semiconductor products located more facilities in North Asia to take advantage of lower labor costs; semiconductor producers have followed them to the region.[17]

There is more pressure to reduce costs. Growing demand for mobile phones, wearables, and automotive devices is projected to increase demand for semiconductor products. However, prices for these devices are expected to decline as competition increases.[18] As the Chinese government invests more than $161B (USD) to develop a domestic semiconductor device manufacturing industry within the country,[19] companies can expect extra attention on lowering supply chain costs to offset the pressure on profits.

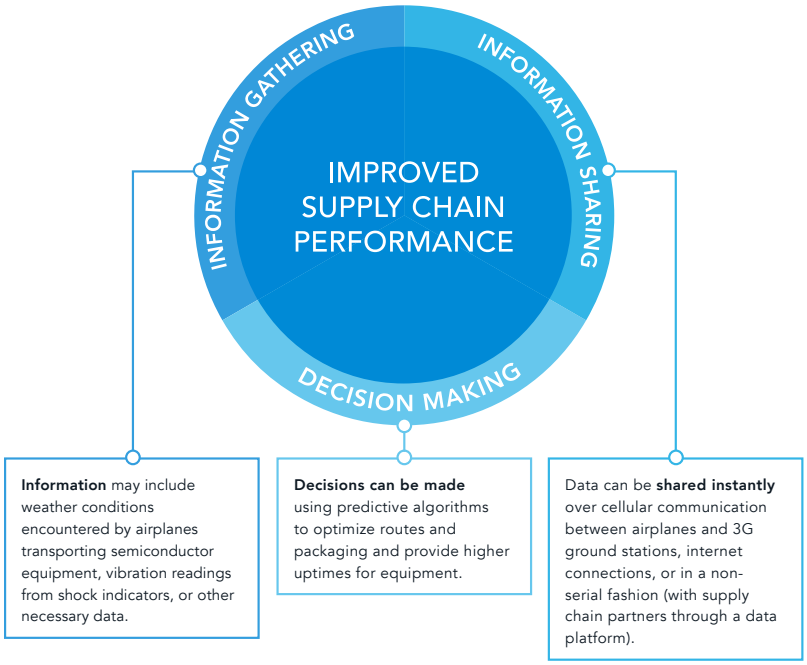
More U.S. equipment is being transported to Asia. In 2016, 90 percent of U.S.-produced semiconductor equipment manufacturing industry's revenue ($8.6B [USD]) was generated from exports, most of which went to Asian countries.[20] Exports as a share of revenue have increased from 51.1 percent in 2011 to 90.0 percent in 2016.[21] It is likely that demand for sophisticated equipment—the type that is usually produced by U.S. manufacturers—will continue in the near future. The growth of this market may have begun already; a rapid acceleration began in October 2016. That month, the market increased 20 percent year over year from October 2015, and year over year increases had climbed to 52 percent by January 2017.[22] Rising demand at this level would require transportation capacity planners to develop more robust Asia region capabilities.

Process equipment requires specialized handling. Etching, photolithography, chemical vapor deposition, and other equipment are key inputs to the industry.[23] Typically, they are shipped by air. The equipment is sensitive to shock, and requires careful packaging

and special handling to prevent damage. Some companies attach sensors (e.g., tilt watches and shock indicators) to shipments to detect impacts that can damage equipment in ways that aren't obvious to the naked eye. Shock indicators are currently activated on 30 percent to 50 percent of shipments from the United States to Asia, according to one industry estimate.[24]

FIGURE 3

Applying the framework to the semiconductor industry



Opportunities to improve performance of semiconductor supply chains with IoT

Use real time information to address possible supply chain disruptions. As manufacturers attach IoT shock indicators to more semiconductor shipments, air carriers can collect and transmit data about vibrations in transit. On the ground, the air cargo receiving team would receive alerts when the airplane experiences excessive turbulence. The team could intercept and inspect potentially damaged shipments before bolstering the packaging and sending the cargo to a customer via surface transportation.

Influence routes for equipment transportation. Companies could combine detailed data from shock indicators on equipment with weather reports and flight information to identify the conditions under which damage tends to occur. Predictive models could compare specific origin-destination pairs with weather forecasts for scheduled flights to anticipate potential high-magnitude shocks and use alternate routes where necessary to prevent damage.

Improve packaging for equipment transportation. Data can be used to optimize equipment packaging before transportation. Packaging expertise varies from one country to another—not just between shippers and carriers, but also among cargo handlers at airports and ports. IoT can provide intelligence on packaging successes and failures, freeing shippers from having to rely on suppliers that simply "know how" to package the goods.[25] Overall, the data can aid end-to-end transportation packaging, handling, rigging, and transport to reduce the likelihood of damage.

Optimize the supply chain to improve competitiveness. Semiconductor manufacturers compete based on "price, product quality, product and process technology, brands, and timeliness of deliveries."[26] Price and timely deliveries are controlled directly by supply chain practices. Using real time IoT data on inventory levels, logistics service providers can manage replenishment and reduce safety stock inventories and operating costs. They can lower administrative costs by automating supply chain planning tasks, such as replenishing wafer and slurry stock. And they can use robust inventory data to create production orders to replenish device inventories.

IOT FOR AUTOMOTIVE SUPPLY CHAINS

The automotive industry is global, with a significant presence in Asia (see Figure 4). Almost half of global auto sales (49 percent)[27] are expected to be generated in Asia. China is the world's largest auto market; the country produced 34 percent of the 94.9 million vehicles produced globally in 2016,[28] and production has experienced 11% year-over-year growth since 2011.[29]

Vehicles are manufactured from over a dozen subassembly systems, including engines, transmission, body and structure, exhaust, electrical and electronics, wheels and tires, etc. Major original equipment manufacturers (OEMs) assemble the final product (e.g., a vehicle) for the consumer marketplace. The OEMs rely on tier 1 suppliers to directly provide subassembly systems (e.g., exhaust gas sensors). Tier 2 suppliers are key vendors to tier 1 suppliers.

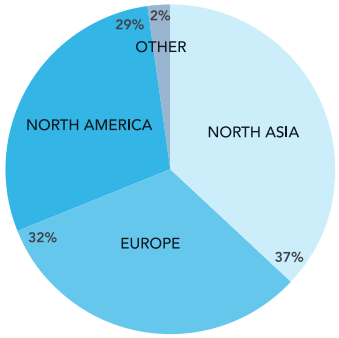
FIGURE 4

The global automotive industry

2016 industry value
$10.4T (USD)[30]
Value of global tier 1 companies supplying non-engine parts[31]
$1.7T (USD)

Leading automotive OEMs[32]	
1.	18% Asia (Toyota 10%, Nissan 4%, Honda 4%)
2.	14% Europe (Volkswagen 9%, Daimler 5%)
3.	14% U.S. (General Motors 7%, Ford Motor Co. 7%)
Largest tier 1 suppliers and their production facilities[33]	
1.	Robert Bosch (Germany): 270 sites in 50 countries
2.	Denso Corp. (Japan): 189 sites in 35 countries
3.	Magna (Canada): 309 sites in 29 countries

Top 75 tier 1 suppliers[34]



Attributes of automotive supply chains

Automotive supply chains are widely dispersed globally. Many countries are involved in manufacturing vehicles, or in supplying the subassemblies for production. In 2016, 19 countries produced at least 1 million vehicles; 34 produced at least 100,000.[35] The market of tier 1 suppliers is highly fragmented. The top 75 tier 1 suppliers own only 43.3 percent of the global market, and the largest tier 1 supplier, Robert Bosch, has a 2.7 percent market share.[36]

Supply chain management has long been strategic. The auto industry pioneered supply chain revolutions in mass production and just in time (JIT) management, and those concepts remain an important basis of competition in the industry today. OEMs compete based on price, quality, and product innovation; tier 1 suppliers compete on supply chain performance (price, customer service, delivery time) and technical competence (engineering excellence, technology leadership, etc.).[37] Tier 1 firms also use strict supply chain performance metrics for selecting their tier 2 suppliers.[38] Auto supply chains in developed countries are lean and often operate with a few hours of inventory. Chinese automotive OEMs, although not as advanced in lean management as Western firms, are migrating to JIT management.

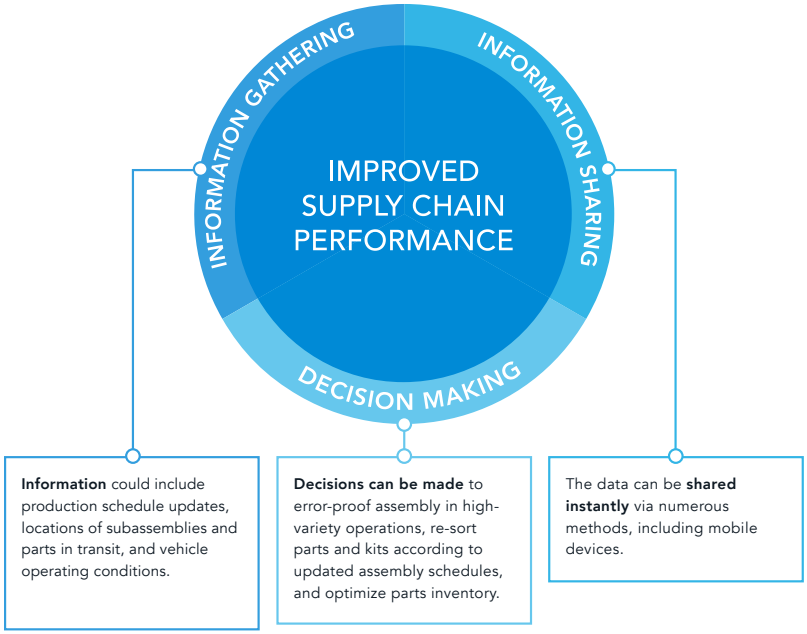
Visibility in supply chains is important, but challenging. Supply chain visibility remains a challenge in the automotive supply chain. In a 2016 survey, only 13 percent of the 360 responding senior executives in six industries, including automotive,[39] reported having visibility into tier 1 and tier 2 suppliers and beyond. Visibility in automotive supply chains decreases rapidly beyond the tier 1 suppliers.[40] The challenge of low supply chain visibility could increase as tier 1 suppliers expand into regions with low regulation and low labor costs.

"Today, some shippers have carrier and driver requirements around safety or trailer cleanliness just to enter the property. Someday, a shipper or receiver will be saying, "To arrive at my dock, you need to be able to offer real time data about a, b, and c from sensors that we can access. IoT will become an order qualifier, minimum requirement for carriers."

Scott McClelland,
Strategy & Business Development,
Bosch[41]

FIGURE 5

Applying the framework to the automotive industry



Opportunities to improve performance of automotive supply chains with IoT

Require dynamic compliance with OEM or tier 1 schedule changes. Using JIT, OEMs require suppliers to deliver subassemblies to the assembly plant in a predetermined sequence. If the assembly schedule changes, the parts and subassemblies being shipped from tier 1 suppliers need to be rearranged in transit so they can be delivered to meet the modified sequence. Logistics companies can enable this by combining real time tracking data from GPS sensors with OEM schedule updates. The same capability could update tier 1 schedules as disruptions occur upstream. Dynamic updates could minimize the need for human intervention in scheduling.

Investigate vehicle diagnostics and predictive maintenance. Predictive models—either in the vehicle diagnostic system or in cloud-based maintenance software—can process data about vehicle operating conditions (e.g., amount of smoke in the exhaust, engine oil pressure, engine vibrations, and engine temperature) and determine the timing of the next maintenance. The models notify the owner and repair shop, schedule the maintenance, and order the parts to enable faster repair and minimize vehicle downtime. Repair shops can use this data to position parts close to the geographic regions where vehicles

are operated to provide faster response times and reduce overall parts inventory.

Reroute or expedite delivery based on traffic and weather information. JIT inventory management leaves little room for error. OEMs often penalize suppliers for deliveries that are delayed even by a few minutes, even if weather or traffic conditions caused the unexpected supply delays. Tier 1 suppliers typically hold inventories of parts near the OEM assembly line to avoid penalties. Using IoT, logistics companies can offer to integrate the OEM's real time assembly line status, current and forecasted local weather conditions, local traffic conditions, and geographic location of parts for suppliers so they can improve their on time deliveries to OEMs.

IOT FOR ECOMMERCE SUPPLY CHAINS

Ecommerce began as one of the many channels that retailers could use to sell products to consumers. With the proliferation of computing devices and growth of internet usage around the world, ecommerce has emerged as a global industry in its own right. Today, it can be an alternative to brick-and-mortar retail or a complementary capability.

Ecommerce offers transactional capabilities not only for business to consumer (B2C) applications, but also business to business (B2B), consumer to consumer (C2C), and business to government (B2G).[42] B2B transactions for 2013, the most recent information available, reached $15T (USD), with B2C sales at a distant second at $1.2T (USD).[43]

Mobile commerce—or m-commerce—has some unique properties that appear likely to impact supply chain management. M-commerce enables users to access the internet from anywhere without plugging in; users can freely buy or sell goods on the go using wireless handheld devices like smartphones and tablets. M-commerce has implications for disrupting inventory placement, order lead time, and other transportation and logistics planning factors.

FIGURE 6

The global ecommerce industry

Industry value (B2B and B2C)
$16.2T (USD)[44]

2016 WORLD'S LARGEST ECOMMERCE MARKETS

China
$779B (USD) in sales[45]
40% of all global ecommerce sales[46]
Alibaba Group and its 12 subsidiaries=72.6% of China's ecommerce revenue[47]
United States
$395B (USD) in sales[48]
20% of all global ecommerce sales[49]
Amazon.com=20% of U.S. ecommerce sales[50]

Attributes of ecommerce supply chains

Ecommerce allows small enterprises to sell globally. Global ecommerce firms like Alibaba, Amazon, eBay, and others, enable small enterprises to reach global markets.[51] The volume of international postal traffic of small packets, parcels, and packages grew by 48% between 2011 and 2014.[52] Primary exporting regions include developed countries, along with Asia and Oceania.

M-commerce is growing rapidly, and expected to become the main B2C ecommerce channel. As mobile phones become more common throughout the world, businesses can expect to see more m-commerce orders for their products. In China, purchases made over mobile devices reached 38 percent of all Chinese ecommerce sales in 2014. By 2019, m-commerce sales are expected to reach 71.5 percent of ecommerce sales in China,[53] 65.4 percent in South Korea,[54] and 41 percent in the United States.[55]

M-commerce is a primary driver of the "showrooming" effect: consumers can use a mobile device (once limited to mobile phones, but now growing to include IoT-connected devices) to inspect products in a store and then shop for lower prices and buy it instantly online. Or, if one store is out of stock on a desired product, the user can search for and find it at another store nearby to make a purchase. The showrooming phenomenon has been observed for about a decade, and has been cited as one reason for closings of brick-and-mortar stores in economies with high mobile connectivity.

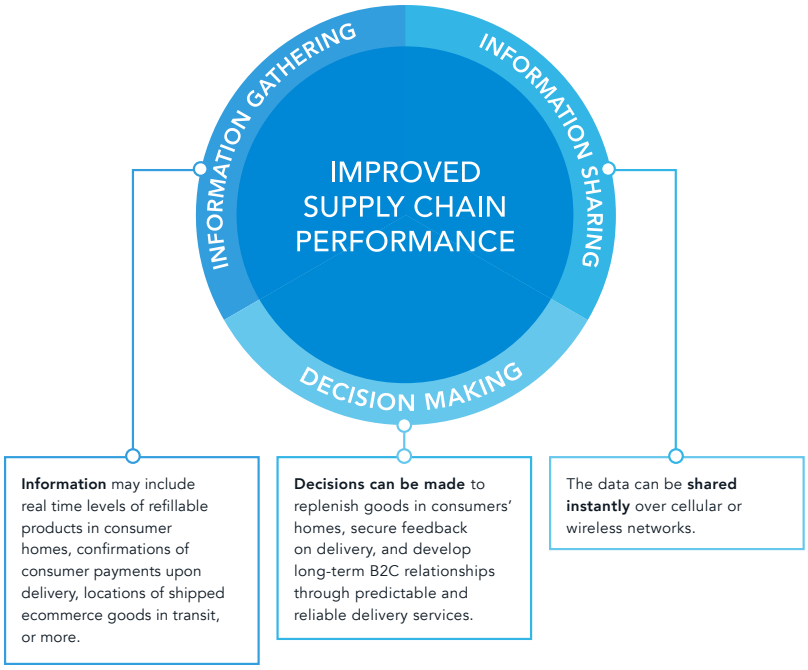
Various payment modes are used throughout the world, and credit cards are not the de facto payment mode. Customers typically pay for ecommerce orders in one of five ways:

- Credit and debit cards
- Electronic funds transfers from bank accounts
- Electronic money (e.g., PayPal, MasterPass, and Google Wallet)
- Mobile payments using near-field communication
- Cash on delivery

Credit cards were used to pay for 71% of U.S. ecommerce purchases in 2012,[56] but the use of this payment method is not as prevalent in other regions of the world.

FIGURE 7

Applying the framework to the ecommerce industry



Opportunities to improve performance of ecommerce supply chains with IoT

Instill greater confidence in online purchases with greater supply chain visibility (B2C). Logistics companies could attach GPS sensors to shipments and offer online, real time visibility to consumers on ecommerce purchases for a small fee. Sensors could provide precise delivery times (better than two- or four-hour delivery windows), and could track packages delivered to a concierge or at a commercial pickup location (such as Amazon Locker) to deter product thefts. Similar sensors could facilitate product returns and expedite the customer credit process. Overall, providing visibility to products in forward and reverse flows could boost customer confidence in ecommerce organziations and purchases.

Enable product monitoring in transit (B2B, B2C) to help small- and medium-sized businesses grow. Ecommerce enables smaller organizations to sell their products to large firms and consumers around the world. Yet, customers sometimes hesitate to buy if shippers cannot guarantee that appropriate conditions were maintained throughout the shipping process (e.g., temperature control of perishable food items). For a small fee, logistics

companies could attach sensors that measure temperature, humidity, and other factors in transit. At delivery, customers could scan the sensor/tag and get a report on the transit conditions, using near-field communication. This capability provides another tool to help small- and medium-sized firms grow their businesses.

Increase automated replenishment of household goods and office supplies (B2C, B2B). IoT trackers can be used to automate replenishments of common household or office items, including smart appliances. For example, HP's Instant Ink printer monitors ink usage and can order replenishment ink cartridges to arrive before the current ones run out. Amazon's Dash service, now available in the United States, Germany, Austria, and the UK,[57] offers "Dash Buttons"—small, thumb-sized devices that consumers can press to order the corresponding product from Amazon.com over a home Wi-Fi network. The Dash Replenishment Service allows manufacturers of smart appliances to add ordering capability so the appliances can order the necessary supplies from Amazon.com (e.g., water filters for a Brita® water pitcher).

Facilitate more m-commerce (B2C, B2B) purchases. Essentially, m-commerce fundamentally changes the demand side of the supply chain, enabling consumers and businesses to make immediate purchases for instant gratification. It makes impulse purchases online much easier and more pervasive than desk-based ecommerce. M-commerce presents at least three implications for demand and management of supply chains that can be facilitated with IoT applications:

1. M-commerce can facilitate greater demand as it allows more impulse purchasing. That is, a greater volume of products needs to be delivered and managed. IoT can connect global transportation technology with SKU-level information, weather, traffic, port activity, and social media insights to help companies gain control and confidence in their visibility and operations. Higher visibility can allow more dynamic, off-schedule replenishments and stock reroutings to prevent stockouts.

2. The ability to compare prices online across brick-and-mortar and online channels may drive prices down in all channels. This can put more pressure on companies to improve cost efficiencies in logistics operations. Companies can alleviate this pressure through better inventory and transportation management

practices. IoT connections can enable more accurate forecasts and predictive analytics and more sophisticated inventory management algorithms across multiple device types and channels.

3. Retailers could respond to this shopping behavior by placing inventory differently to fulfill orders faster. For instance, a retailer could position inventory such that a consumer buying a product advertised in a subway train can pick it up after getting off the train. Inventory could be located in areas with higher pedestrian traffic (such as near train stations) or could be made mobile by using small trucks.

Until recently, m-commerce has been enabled largely by mobile phones. IoT devices also facilitate m-commerce with their portability and ability to connect to the internet anywhere internet-connectivity is available. Thus, the implications of m-commerce will be felt even more widely as the adoption of IoT devices increases.

Consider vendor managed inventory for the home (B2C). As automated replenishment grows, more products will be delivered directly to consumers' homes. This type of automated replenishment could transform the short-term consumer-retailer relationship into a longer-term one. Consumers could outsource inventory management for household goods to the retailer (similar to vendor managed inventory for business) to obtain discounts on their purchases. The retailer would obtain repeat business and dampen demand variability. Logistics companies can be key facilitators of this commerce by providing efficient last-mile deliveries.

Encourage trade with IoT-enabled payments (B2C, C2C). In some parts of the world, consumers still hesitate to pay online for a product before it is delivered. They may not want to bear the risk of obtaining a damaged or lost product, or may not want to deal with trying to obtain a refund. IoT can provide peace of mind for all parties. The consumer could pay for the product through a mobile device—a method that is similar to cash on delivery, although payment is made electronically—after receiving and inspecting the product. The IoT capability could protect the seller by "locking" the product (especially electronic products) until the seller receives the payment and sends a "payment confirmation" signal to unlock the device.

Explore business-to-government opportunities (B2G). The idea behind B2G is that technology platforms can be used to exchange information between businesses and government agencies more efficiently. As IoT devices get used more widely in supply chains, a potential exists to create IT infrastructure to allow the devices to communicate directly with the B2G platform. Such communication could include sharing import-export documents (such as packing lists, bills of lading, and inspection certificates) from containers at ports, truck inspection and weight data with local highway authorities, payment information for import duties at borders, and so on. While several such opportunities can be envisioned, a bigger challenge may be in forming collaborative relationships with government authorities to create the infrastructure and the processes necessary to have the IoT-enabled communication replace the in-person transactions.

Increase visibility to improve cross-border ecommerce (B2G). B2G cross-border ecommerce is growing rapidly, particularly from China to countries like Malaysia and Singapore. The preferred ERP/CRM/SRM systems in use are WhatsApp, WeChat, and other platforms. Visibility is severely lacking. IoT could integrate systems and develop a common platform that would connect ecommerce participants: mega, large, and small suppliers from China, Vietnam, and Thailand; government agencies; and logistics service providers (LSPs). Such systems could help retailers and suppliers grow business while making the supply chain more efficient by speeding the flow of goods. Automating order fulfillment and providing order-level visibility could enable better customer experiences, accurate fulfillment, and real time response.

READINESS FOR IMPLEMENTING IOT TECHNOLOGIES

Despite IoT's unbounded potential to improve supply chains for specific industries, several challenges must be resolved before the ideas that are envisioned can be implemented.

Ambiguous terminology.[58] Internet of things is one of the widely used phrases in business literature. It is often used interchangeably with other related and unrelated phrases, including the internet of everything, internet of cars, Industry 4.0, and so on. Organizations should take the time to level-set the definitions of this and other ambiguous terms so everyone understands the terminology being used to discuss what is possible with IoT applications.

"In the next 10 years, the Internet of Things revolution will dramatically alter manufacturing, energy, agriculture, transportation and other industrial sectors of the economy which, together, account for nearly two-thirds of the global gross domestic product (GDP). It will also fundamentally transform how people will work through new interactions between humans and machines."

World Economic Forum[59]

Lack of an IoT strategy. When Boston Consulting Group (BCG) surveyed 380 executives in 2016, 53% of the respondents confirmed that IoT and Industry 4.0 should be priorities for their organizations. But BCG noted that "many U.S. manufacturers are moving too slowly to adopt Industry 4.0."[60] Respondents also indicated that defining an IoT strategy and rethinking organizational priorities were the two biggest challenges in adopting IoT. To overcome this challenge, companies can develop a systematic approach when envisioning how IoT capabilities could improve organizational processes. By experimenting, they can test and refine ideas on a small scale before larger deployments.

Determining how widespread the investment should be. Using IoT to manage supply chains requires investment in sensors and communication/data-gathering devices. The payoffs from such investments are unpredictable unless the investing firm has a very clear strategy for using the IoT capabilities. Small firms—from owner-operator trucking companies to small logistics, retail, and manufacturing firms—may not be ready to invest in IoT, especially when they operate in a cost-competitive environment. Firms should work with and discuss IoT concepts with trading partners, and everyone should agree in advance who will make the investments and accrue the benefits.

Concerns with data confidentiality. Companies are understandably concerned about data ownership, security, and privacy. Firms must discuss these concerns with customers, suppliers, and logistics partners before sharing private information about orders, inventory levels, shipments, and capacity usage. If a logistics company will provide IoT applications hosted on proprietary servers, they may need to provide assurances about data privacy, physical location of data servers, etc., just as IT companies do for their cloud solutions.[61] Companies that host the IoT application on a non-proprietary, third-party, cloud-based platform may face additional hurdles stemming from data privacy concerns.

Lack of available talent with knowledge of IoT applications. In 2015, an estimated 4.5 million individuals were active as IoT developers worldwide; most were professional developers creating mobile apps and IoT applications for manufacturing.[62] But many of the applications created so far for smart homes, wearable devices, and connected cars were developed by amateur hobbyists and explorers. With data confidentiality so critical to businesses, companies will need to identify more professional IoT developers, who will be able to develop

applications that protect data confidentiality and security. Finding enough qualified developers could influence the rate of the technology's adoption in business.

Reliable electric power supply and network connectivity. IoT implementations could face additional challenges in developing countries where electricity supply is not reliable, unless continual power supply can be guaranteed using batteries. Similarly, devices will need to have adequate internet connectivity to exchange information over the gateway. Availability of network coverage will influence IoT adoption rates in specific regions, particularly in remote geographic areas.

3 WAYS TO EMBRACE IOT FOR SUPPLY CHAIN MANAGEMENT

The IoT revolution is just beginning, and is likely to transform supply chains worldwide. This is an information technology revolution. Firms that can creatively imagine, combine, and interpret various types of data through information platforms are likely to be the big winners. The IoT-enabled opportunities for improving supply chains are limited only by the bounds of our creativity. A framework, such as the one in this paper, can help envision these opportunities, deploy IoT capabilities, and improve supply chain performance. The following factors will be key to unlocking IoT's potential:

1. **Understand the industry's challenges.** To conceive IoT solutions, identify and understand present-day supply chain challenges that need to be overcome. Also understand the industry's capabilities, and be prepared to exploit them through novel IoT products and services.

2. **Recognize that novel applications will most likely arise by combining different types of data.** Think of different aspects of a supply chain that could be measured using IoT devices, and how that data might be combined with other information to generate insights about a supply chain's performance. Understanding the platforms that provide a variety of data can be helpful in this regard, as well.

3. **Be aware of the obstacles that could derail solutions.** This paper lists a few potential obstacles that must be acknowledged and addressed. But adopting brilliant technical solutions could be hindered by people who fear data sharing, or who lack a clear understanding of the technology or an overarching strategy.

END NOTES

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END NOTES

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