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# How Can the Internet of Things Reduce

Waste in the Supply Chain?

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Introduction

As of 2020, it is expected that the number of devices sharing data between themselves about their human operators will reach over 30 billion (Columbus, 2016). While society hasn't yet reached a point where a robot takeover should be a pressing concern, this communicative technology is prevalent in the lives of many who are oblivious to its existence. Many people don't realize that their everyday technologies—their cars, refrigerators, thermostats, and mobile phones, to name a few—are collecting data and having conversations amongst one another about them. This concept, known as the Internet of Things, is happening whether or not it is realized, and it is important to understand what impacts can be expected to have on society.

Figure 1: Growth of IoT Devices: 2015-2025
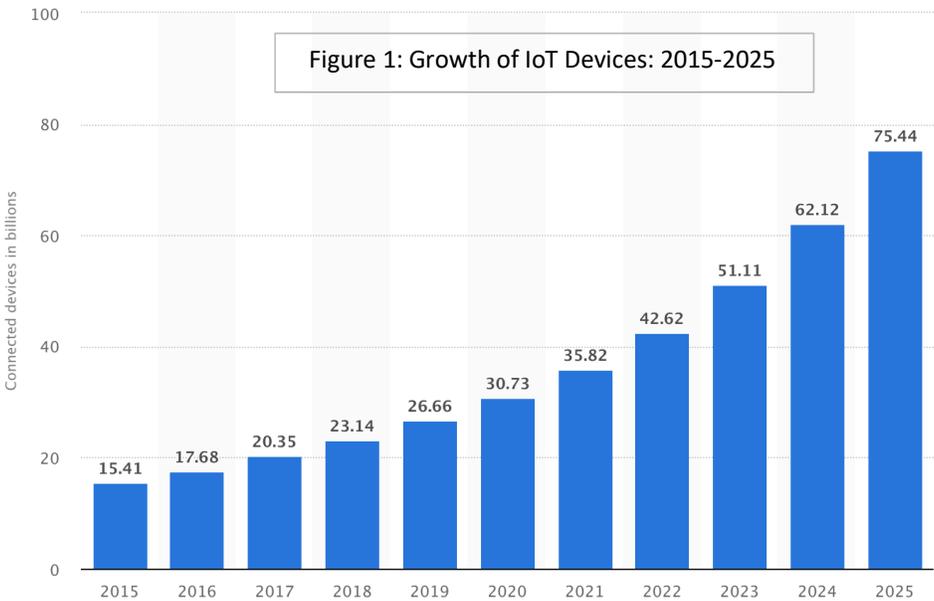
In the technology assessment, *Internet of Things: Status and Implications of an Increasingly Connected World*, performed by the United States Government Accountability Office, it was found that "electronic processors and sensors have become smaller and less costly." Additionally, IHS Markit, a company in the critical information and analytics sector, projected a 389.6% increase in the number of Internet of Things (IoT) enabled devices globally

from 2015 to 2025. Essentially the ability to produce IoT devices is becoming increasingly easier, which is a prominent catalyst in the exponential explosion of IoT devices produced worldwide. Knowing that, one of the biggest uncertainties about IoT devices going forward is how to most effectively utilize the massive amounts of data that the devices generate.

The Internet of Things is a relatively new phenomenon in which inanimate devices communicate with one another by sharing data, which is possible through sensor technology that enables the interconnection of these devices. The key benefit of IoT is time savings through performance optimization. To name a few, current IoT technologies speed up need recognition and ordering processes, which makes stockouts more unlikely by tracking inventory, alerting users when new product needs to be purchased, and implementing quality controls. However, because the Internet of Things is in such an infancy stage, possibilities as to what IoT can do for businesses and the supply chain industry as a whole are simply infinite and unknown.

Although the Internet of Things is so preliminary that it is not fully known or understood what it can or will be able to do, there is a huge opportunity to reduce waste within operations for many businesses when IoT becomes more fully developed. My specific focus will be to assess how IoT generated data can be used to reduce seven types of waste—known as the "Seven Deadly Wastes"—which include: inventory, waiting, motion, defects, transportation, overprocessing, and overproduction. Ultimately, mitigating these wastes will improve efficiency in lean supply chain processes.

Figure 2: Seven Deadly Wastes of Supply Chain

Inventory — Excess products and materials not being processed.

Waiting — Wasted time waiting for the next step in a process.

Motion — Unnecessary movements by people (e.g., walking).

Defects — Efforts caused by rework, scrap, and incorrect information

Transportation — Unnecessary movements of products & materials.

Overprocessing — More work or higher quality than is required by the customer.

Overproduction — Production that is more than needed or before it is needed.

My study should be of interest to a wide variety of companies in the supply chain world because of how many nodes within a supply chain the Internet of Things has the potential to impact. To name a few, manufacturing companies, transportation companies, and retail companies have huge opportunities to implement new IoT strategies to improve their operations—at this time, these kinds of companies are already familiar with the concept of the Internet of Things, but there is so much room for growth of this technology that their current applications are likely to become obsolete in the near future. Essentially all nodes along the supply chain can be positively affected by improved Internet of Things utilization, which is why it is important to assess how IoT can be used across the industry in order to capitalize on this opportunity.

By interviewing supply chain managers working in various industries, the following themes emerged as ways to improve supply chain operations through IoT usage and are covered in this study:

1. Improved Visibility Along the Supply Chain

2. Controls to Enhance Product Protection

3. More Efficient Movements

4. Better Understanding of Consumer Needs

It is important to note that different industries and businesses may vary in how they operate, so not every business will have the same abilities or successes when implementing the suggested strategies. The goal is to establish a methodology that businesses can reference when improving operations through Internet of Things applications to achieve key performance outcomes. The best practices for the Internet of Things uses are described in the following study and are meant to be adjusted to meet individual company's needs based on the scope of that company.

Improved Visibility Along the Supply Chain

A concept very often discussed in the supply chain realm is the Bullwhip Effect, which describes a distortion of demand that increases as nodes get progressively farther upstream in a supply chain. Because they are closer to the end customer, companies that serve as downstream nodes in the supply chain have a much more accurate depiction of what demand actually is, but the disconnect arises between more upstream nodes. Each additional upstream tier is an additional tier removed from knowing actual demand. Essentially, upstream suppliers have a more limited visibility as to what actual demand is due to a lack of communication between nodes, thereby causing massive forecast inaccuracies (Hau).

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Figure 3: The Bullwhip Effect

The Bullwhip Effect exists as a result of the limited availability of resources and the inept abilities of existing technology to provide full visibility of accurate demand forecasts to upstream suppliers; this obstacle is the root of the most common and impactful supply chain waste: overproduction. It is commonly known that the cost of holding inventory is less than the cost of a stockout because stockouts can result in lost customers, and the impact of a single lost customer is so much greater than just one customer. Therefore, it is common that companies air on the side

of higher production quantities even though this incurs unnecessary costs and adds to their overall wasted product.

The lack of end-to-end visibility as a result from underdeveloped technologies is hugely wasteful. However, because a reason as to why the Bullwhip Effect exists has been identified, companies can work to mitigate the issue. Current technologies can be better utilized and developed to reduce overproduction waste, and the recent rise in popularity of Internet of Things technology provides the opportunity to reduce waste should IoT be utilized to its fullest potential.

The key to using IoT to improve supply chain visibility is through sensors. Sensors constantly collect data that reflects where products are in the production process. The development of smaller and less costly sensors is revolutionary in this endeavor. For these efforts to be successful, all nodes of the supply chain should have access to the data that is collected by these sensors. As the distortion of demand is lessened or removed, upstream supplier will be able to produce quantities more closely aligned with actual demand. This can reduce safety stock, stored inventory, and obsolete inventory levels, which largely constitutes overproduction waste. Knowing end consumer demand effectively can eliminate overproduction waste.

Sensors can also be used to understand the physical location of product within a specific facility in real-time, which can reduce inventory mismanagement waste. Within a facility, using drones and implementing a Wifi Inventory System can use geolocations to collect detailed data about inventory location. Through this system, each piece of inventory is tagged using sensors as it comes into the building and then each movement within the building is tracked using IoT technology until it leaves the building. Having this data allows for a reduction of physical

inventory and inventory cycle count—impacting overproduction waste—as well as an improvement in location accuracy—impacting inventory waste.

While knowing demand is a fairly obvious desire for upstream supply chain members, it is equally impactful for downstream members to have end-to-end visibility of the supply chain. Downstream nodes should have access to upstream production information about specific product—whether that be what quantity is being produced or what stage of production the product is in; having this knowledge will allow them to better plan for how many products are available for purchase as well as when shipments can be expected to arrive based on the capacity constraints. Utilizing IoT technologies can allow the upstream supply chain to monitor all production data in real-time and to communicate that with their consumers.

IoT improvements will be a prominent catalyst in attaining full supply chain visibility and in reducing several kinds of wastes including overproduction and wasted inventory. However, the capability of understanding demand necessitates the ability to know where products are—physically or in the production process—because knowing perfect demand is somewhat meaningless if there is no way of knowing if the supply chain can meet it. Ultimately, accurately knowing the upstream capabilities in terms of capacity and production quantities is just as important as knowing downstream demand in terms of achieving full supply chain visibility; coupled with the Internet of Things, this understanding of true visibility has great power to reduce supply chain waste.

Controls to Enhance Product Protection

Another supply chain waste that exists are the defects and errors that necessitate rework. One of the largest causes of this waste is the spoilage of products. While different products

require different controls to remain viable, current technologies that exist typically provide controls that are set to specific temperature or humidity requirements. However, these technologies are currently very elementary in terms of the prevention of product spoilage. Involving more advanced technology that is IoT enabled can allow real-time monitoring of product, which is key to fully protect products.

The benefit of real-time monitoring is a new idea that could dramatically reduce waste caused by defects and errors. For example, many types of food must be refrigerated within a specific temperature range in order to remain fresh in transportation and storage. In the past, these products have been stored or shipped initially within their required temperature range, but frequently, only after unloading shipments or unpacking stored products is it identified that the temperature fluctuated outside of the required range unbeknownst to any employee, making the product unsellable. Now consider this situation but with an IoT enabled device that monitors temperature. This technology provides the ability to see in real-time if a control is about to fall outside of the acceptable range, which allows for the opportunity to fix the control issue in order to maintain the life of the products in question.

This same ideology can be applied to protect products against various kinds of spoilage; many types of controls are needed to keep products viable—to name a few, consider flowers that would wilt if not kept within proper humidity limits, nuclear products that require specific pressures to prevent unwanted explosions, or fragile packages that would break should the packages move around significantly in transportation. IoT technology can control for these criteria among others in order to maintain the viability of the products in real-time through the use of sensors.

Another common concern among members of the supply chain is the safety of packages in transportation and products in storage. It is expected that when unloading a shipment or locating a product in storage, all anticipated items should be accounted for and in the condition as they were initially shipped or stored. Unfortunately, more often than desired, packages have been tampered with, opened, or even stolen, which adds to errors waste as it necessitates rework in order to meet customer expectations. However, IoT technology can be used to prevent this. Light sensors can be used to monitor if packages have been moved outside of a specific geolocation or opened in any unapproved location. These sensors will send an alert if the control isn't fully maintained, which would notify a worker to check on the product immediately rather than risking potential theft or product tampering.

While the improvement of IoT technology can identify issues on an individual basis, the greatest area for impact is identifying trends of defect and error waste. Looking at the data over a period of time can allow a company to identify if there is a common theme in when, where, or how waste is occurring. For example, based on the collected data, if a company is able to identify that a specific transportation route routinely flags for pressure drops, they could investigate why this is happening and develop strategies to prevent it in the future.

More Efficient Movements

Transportation Movements

Each activity in a supply chain operation can be classified as either a value adding activity or a non-value adding activity. Ideally, the goal is to reduce all non-value adding activities as much as possible because those activities increase cost without providing any additional value to the end customer. Transportation falls under the non-value adding activity

category, and because it exists between every node of the supply chain, the time allotted to non-value adding activities—specifically from transportation—makes up a fairly significant percent of the total operation time.

Not only is transportation classified as a non-value adding activity, the expectation is that such products are delivered in full, on time, and in spec—abbreviated as DIFOTIS—which gets complicated quickly based on the scope of challenge (Slone 116). There are a lot of variables that impact transportation efficiencies, which opens a lot of room for shipping companies to not meet the DIFOTIS expectation, and while not all those variables are within human control, like natural disasters, it is important to monitor the controllable variables and reduce any variation that can negatively affect transportation efficiencies.

Transportation can be divided into two subcategories: the loading and unloading of products and the actual transport of product. Receivers are allotted a certain time to unload products by carriers. Exceeding that time incurs additional charges from the carrier, so it is in the best interest of the receivers to be as efficient in the unloading process as possible. A product called the Raspberry Pi is essentially a mini programmable computer that can revolutionize the efficiency of the unloading process. Raspberry Pi has only recently begun to be developed for the benefit of the transportation industry; it has been programmed to reduce dock door turnaround times in order to eliminate detention fees and improve productivity of receivers as they load, unload, stage, and put products away in order to get doors turned faster. The Raspberry Pi uses a visual display and a mechanical device that displays a color-coded system to monitor unloading times in order to stay within their allotted times as well provides real-time information about the unloading process. This specific IoT device isn't the only way to improve unloading efficiencies, but it highlights the importance of having the ability to monitor if on-time KPIs are being met in

real-time, which can signal how current work efforts may need to be adjusted to improve on-time percentages as a whole.

The physical transport of a product makes up the most significant portion of time in the supply chain process, and shipment time incurs inventory carrying costs, which is a non-value adding cost for the customer. Therefore, reducing the shipment time will in turn reduce total cost. Regardless of the shipping method, GPS-enabled sensors can be placed on transportation vehicles to monitor routes, and based on the data that is collected, optimized routes can be provided for carriers to follow. After that, continuing to monitor the locations of transportation vehicles can ensure that vehicle operators are following routes, are maintaining proper safety protocols like the number of hours continuously driven at one time, are avoiding delays, and are not adjusting work-related routes for personal reasons.

Because transportation is non-value adding, it is an area for continuous improvement. Coupling improved unloading and loading efficiencies with improved route efficiencies will cut costs and dramatically decrease the amount of transportation waste that exists in the supply chain, but this goal can only be achieved through the use of IoT technologies and focusing on maintaining that high standard of DIFOTIS.

Movement within Facilities

While the future may find that increasingly more work within the supply chain is executed by robots, at this time, there is still a large human component within the operational side of the supply chain. Therefore, it is important to look into worker performances to understand where there is room to reduce human motion waste.

Looking at the travel footprint of each worker within a facility allows for an understanding if workers are being as efficient as possible in how they fulfill orders, but doing so would require that workers are trackable through the use of a sensor. This endeavor should not be put in place as a punitive measure, rather it should ensure that each worker moves product properly and efficiently. Tracking where and what workers are doing in a facility can allow companies to identify what wasted movements exist on an individual level and if there are trends of wasted motion among specific facilities. Collecting this data can allow facilities to be more efficient and can improve worker productivity by cutting out motion waste.

Better Understanding of Consumer Needs

At the end of every supply chain is the consumer. Therefore, even as a company that isn't selling directly to those end consumers, the needs and wants of the end consumers are still pertinent in the decision-making process regarding how the business is run.

As previously mentioned, one of the benefits of increased usage of IoT is improved visibility, and that initiative begins with the consumer. Obtaining a better understanding of consumer demand is the first step to achieving perfect visibility within the supply chain. Using IoT necessitates sensors everywhere, and that is true at the consumer level as well. The world is becoming increasingly more digital, so there is a huge opportunity for companies to provide IoT enabled products to consumers in order to better understand consumer habits and needs (Barkakati). Consumers are continually looking for ways to make their lives easier through the use of products, so if companies are able to capitalize on that desire by providing IoT enabled products to the consumer, they will have an abundance of data that provides massive insights on the wants and needs of the people purchasing their products.

Essentially the goal of purchasing products as a consumers is to improve their lives through the use of those products. If companies use those products to collect data on consumers, they will likely recognize patterns about consumers, which gives insight on how to better capitalize on their needs and wants going forward. The difficulty of this is that consumers often don't recognize what they need to improve their lives, but the more that is understood about consumer habits and needs through data analysis allows companies themselves to identify where those needs exist and develop consumer products to fill that need. Doing so can create additional sales for the company and a competitive advantage over competitors if other products don't already exist to fill that need. Better understanding the consumer can reduce overproduction waste in that the production of products that are not wanted or needed can be minimized or reduced.

Depending on the type of company and what their products are, data collection through sensors will provide overwhelming amounts of data. Based on overall trends that the data exhibits, to reap any benefit from their data will require that companies adjust their strategies going forward. Using the data will provide more granularity into current models and applications of those models—in short, which products are doing well and which are not. Once that is determined, companies can fine-tune their models to better meet customer needs by adjusting what products they produce, what quantities they produce them in, and when to produce them. Ultimately, refining models to better meet customer needs can reduce obsolete inventory in the future, thus reducing inventory waste.

Additionally, refined models allow companies to recognize opportunities for cost savings through quality improvements. With IoT technology, companies may recognize that their products are defective or if quality systems aren't operating properly much more quickly than

without that technology. In the past, companies often didn't see these issues until the product was in the hands of the consumers, which can be a costly endeavor to correct. Identifying if there is an issue with a specific product in real-time can reduce defective product waste rather than recall products after they have been purchased by consumers.

Ultimately, using IoT technology to better understand consumers impacts all other aspects of the supply chain including visibility, controls, and efficient movement. Without this knowledge, supply chain as a whole would be a lot less strategic and ultimately incur a lot more waste and costs. However, through strategic supply chain operations and IoT enabled devices for consumers, a ton of waste—including inventory waste, defect waste, and overproduction waste, to name a few—can be avoided.

Problems and Concerns

As with anything new, there will be concerns that arise with exploring unknown territory. In their interviews, the supply chain managers identified the following three themes that summarized their main concerns with IoT, though it is worthy of mentioning that all interviewees said they approve of continued use of IoT devices:

1. Potential Lack of Feasibility
2. Negative Impact on Consumers
3. Lack of IoT Standard Across all Industries and Companies

Potential Lack of Feasibility

In theory, obtaining end-to-end visibility along the entirety of the supply chain sounds momentous, and it definitely would be if fully implemented. Successfully utilizing the Internet of

Things across all industries would dramatically reduce waste and improve the efficiency of operations. However, a huge concern exists regarding the feasibility of this IoT initiative.

Achieving true end-to-end visibility would require such massive collaboration between every single node along the supply chain. That raises the question: are such high levels of collaboration on a consistent basis feasible? Firstly, all members of the supply chain would have to be willing to put in the effort to collaborate. Additionally, this collaboration would be so heavily reliant on the hardware that comes with the Internet of Things, and being that the Internet of Things is still in its infancy stages, it is not currently understood what the long-term viability is for IoT devices. Until it is known how long the devices will last and what the total cost of ownership is, the concern will remain: is it worthwhile to invest in something that may not be reliable in the long run?

Fully and successfully implementing Internet of Things technologies would require enormous numbers of sensors to collect the data necessary to improve supply chain efficiencies; it may require sensors on every item pertinent to a supply chain, which is excessively expensive. The cost of implementing IoT may not be a concern to companies that currently realize high profit margins, but lower profit industries will question the financial feasibility of IoT especially if the success and long-term viability of IoT hasn't been confirmed. There is a tradeoff that must be determined—as a company, what level of visibility is worth paying for?

Negative Impact on Consumers

The most downstream node of a supply chain is the end consumer, and the production of any product, regardless of the industry, is dependent on if, when, and how many units end consumers want. Therefore, being that the goal of IoT is to reduce waste, the ability to forecast

end consumer demand with 100% accuracy would be vital to the success of waste reduction, which would entail having data-collecting sensors on final products that end consumers purchase, but collecting data on consumers raises a lot of potential concerns.

Consumers need to know that the IoT devices they purchase are producing data, which is collected and analyzed. Not only do consumers need to know that data is being collected, but they also need to understand what the data says about them. Many stores collect data on customers through loyalty card programs, which keeps data on what products they buy most frequently. The stores can then use that data to retain the customer, typically through incentives like coupons, but this is a very elementary form of data collection. However, companies use IoT data to analyze on a deeper level how consumers interact with the world. This data becomes more personal, which has the potential to become disadvantageous to the consumer. For example, an insurance company could look at an IoT-enabled vehicle to determine that someone is driving too fast or too recklessly and raise the cost of insurance for that customer.

Consumer data is very valuable as market research but can be very personal, so people with access to that data must be careful to not unethically spread that data without the consumers knowledge. Additionally, collecting data via an IoT device opens the door for potential security breaches which would expose confidential consumer data. Any internet-enabled device has the ability to be hacked, and many companies that currently utilize IoT for end-consumer data collection haven't taken the time to put in place proper safety measures to prevent these hacks.

Lack of IoT Standard Across all Industries and Companies

As previously mentioned, IoT technologies heavily rely on sensors to provide a benefit to companies. These sensors collect large amounts of data, which are transmitted to an internet-

based platform—whether that is a network, a cloud-computing platform, or a processor. This data is stored and can be analyzed. However, it can also be hacked. As a result, increasing the implementation of IoT technologies may be a substantial contributor to security vulnerabilities (Dellinger).

Currently, there is a widespread lack of awareness regarding how the technology behind IoT works, even among the companies that are currently utilizing the technology. As the number of IoT enabled devices is exponentially increasing, more and more users will have access to the devices. Do all of these companies using IoT data and producing IoT enabled devices know what they are doing and how to implement proper safety measures? The simple answer is no.

Forty-eight percent of businesses, no matter what size, have experienced a security breach resulting from a lack of proper safety measures. Impacts of security breaches can vary in severity from temporarily losing access to networks to tangible losses in revenue (Dellinger). One of the most severe security breaches of an IoT system was the breach of the DNS system in October of 2016. The DNS system is essentially the backbone of the internet as it is what allows users to access websites through the use of IP addresses. When this attack occurred, 17 of the top 100 most visited sites, including Twitter, Netflix, Spotify, and Paypal, were inaccessible for close to half a day (Tran). To put that in perspective, imagine if Google had been one of the sites that was attacked, even if only for five minutes—forty percent of the global internet would be negatively affected; the amount of economic chaos that would arise is truly unconceivable.

Companies that haven't experienced security breaches have invested 65% more on strengthening their security measures than those who have been breached (Dellinger). Consumers download apps without understanding how their data could be impacted, and this likely won't change, so it is the responsibility of the company to know how to protect their

customers' data as well as their own. While the largest security breach of IoT to date simply shut down parts of the internet for several hours, what attacks could be next? If IoT standards aren't established or if companies don't begin to invest more money into security, the next attack could be more sophisticated and shut down more critical infrastructure systems such as banks or healthcare systems.

Today is just the preliminary phase of IoT, but one day, everything will be connected to the internet in some form, and those connections are becoming more non-traditional as the Internet of Things develops (Giardi). Because companies aren't implementing proper procedures now to protect data, increasing amounts of data will continually be exposed to potential hackers. If data isn't protected in now and no changes are made to protect it in the future, what is going to happen when IoT is more developed or when more sophisticated types of data exists to be hacked? Security of data is one of the most pressing concerns of the increasing usage of IoT devices, and because there is no current standard in place for how to make and use IoT enabled devices, security will always be the main IoT concern until that changes.

Conclusion

A common analogy regarding waste used in the supply chain world considers a boat on a river. The boat will float down the river with ease unless water levels decrease, which would cause the boat to hit large rocks hidden at the bottom of the river. The success of a supply chain, represented by the boat, is obscured by high levels of inventory, represented by the water, but when inventory levels are decreased to more
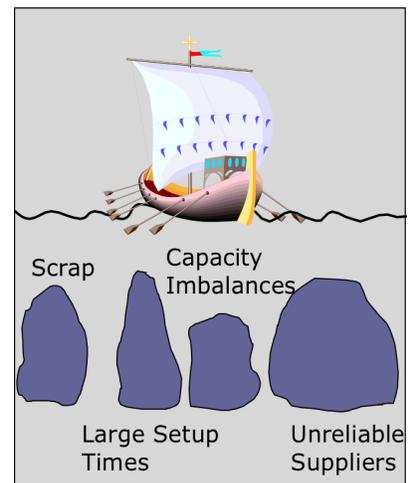
accurately reflect what demand is, actual problems in the overall supply chain, represented by the rocks, become evident. While this analogy is somewhat simplified of reality, it drives the point that overproduction creates excess inventory, which can hide real performance and operational obstacles as well as other forms of costly waste. To maintain true supply chain success, companies will need to slowly reduce over production waste until the first rock is identified; once identified, these rocks, or obstacles in the supply chain, will need to be addressed in order to continue reducing overproduction waste (Asef-Vaziri 3). Doing so allows for a reduction of hidden obstacles and waste to create supply chain success.

Individual companies will have to identify what their specific wastes are and determine which obstacles they want to tackle first. Many companies looking to reduce waste and improve efficiency have taken the plunge into the IoT world and are reaping benefits from it. The application of Internet of Things enabled devices is still very elementary, but the potential for waste reduction is great. Sensors are the backbone of the Internet of Things and its success, and they are the catalyst behind how IoT can reduce waste in such a dramatic way. As the number of IoT enabled devices continues to increase exponentially, the companies who are able to capture their benefits focus on improving visibility, monitor controls to enhance product protection, ensure more efficient movements, and better understand consumer needs have the opportunity to beat out competitors and achieve key performance outcomes on a consistent basis.

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