Deloitte.

Using smart sensors to drive supply chain innovation

A series exploring Industry 4.0 technologies and their potential impact for enabling digital supply networks in manufacturing

Contents

Do you need smart sensors in your supply chain?
Smart sensors transform the physical world into digital insights that are used to create new value across the supply chain. By arming managers with real-time information about their inventory, machinery, and purchased materials, smart sensors create visibility across the supply chain and fuel analytics that can be used to understand and anticipate demand, optimize sourcing, and drive high-value manufacturing decisions.

Of interest because: The ability to provide relevant, timely data regarding both products and conditions can be used to generate a more holistic, accurate perception of the operating environment. Smart sensors create the "digital last mile" of a fully connected, always-on supply chain—a digital supply network—that brings the company end-to-end visibility into its suppliers, distributors, and customers.

Could improve your supply chain by: increasing operational efficiency, lowering production costs, and providing critical insights into customer behavior. Smart sensors introduce automated monitoring processes, such as inventory counts or predictive maintenance, improving both labor productivity and performance accuracy. By embedding smart sensors into products, companies generate awareness of usage trends that can be used to inform future product development and improve after-sale service offerings.

Why not? Investment in supporting technology, limited internal functional expertise, or an unwillingness to redesign processes may deter some companies from adopting smart sensors in their supply chain. A number of enabling technologies—in-house data aggregation platforms, plant bandwidth, data encryption, and several others—are required to create value through a smart sensor strategy. Having the technical skill sets for interoperability is also a prerequisite to smart sensor integration. Moreover, companies need to possess the willingness and flexibility to implement or replace processes in their supply network to unlock the benefits of smart sensors.

Deloitte recommends: With the introduction of reliable IoT platforms and advancements in technologies that have both accelerated performance and reduced costs, traditional barriers to smart sensor adoption are eroding. Companies should consider investing in smart sensors to increase value capture through their supply chains after carefully prioritizing their business objectives and defining their use cases.

What are smart sensors?

Overview

A sensor is a device that provides feedback on a physical process or substance in a predictable, consistent, and measurable way. Smart sensors are different from sensors in that smart sensors are advanced platforms with onboard technologies such as microprocessors, storage, diagnostics, and connectivity tools that transform traditional feedback signals into true digital insights.[1] These smart sensors can provide the timely and valuable data underpinnings to power analytical insights that can in turn drive improvements in cost, performance, or customer experience.
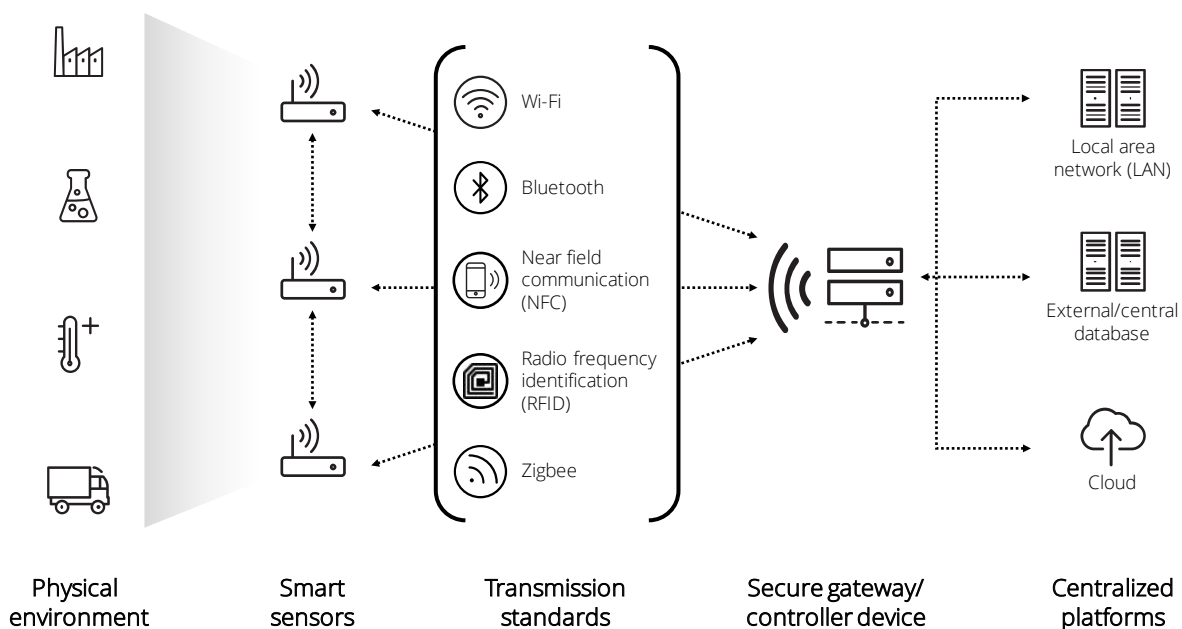
Ecosystem

A differentiator of the smart sensor is its role in the broader information and analytics ecosystem. The accelerated exchange of physical-turned-digital information can exponentially increase the range of opportunities for increased performance, higher capacity, greater reliability, and advanced innovation. Five primary interface methods—digital, logic, voltage, current, frequency, and phase—convert observed inputs into digital form. Transmission standards such as Wi-Fi, Bluetooth, NFC, RFID, and others are then used to communicate this data to other sensors, controller devices, centralized management platforms, or distributed computing platforms for data aggregation and analysis (see figure 1).[2,3]

Recent developments and outlook

The global smart sensor market is growing at a 19 percent annual rate and is expected to reach $60B by 2022.[4] Technological advances have miniaturized the devices, improved performance and energy efficiency, and reduced production costs.

Smart sensor computing capabilities have strengthened substantially, thereby enabling data processing and analysis at or near the source ("edge computing") and reducing the amount of data that moves between the device and platform. Additionally, the introduction of micro-electro-mechanical systems (MEMS) technology has allowed for more compact, higher functioning smart sensors by effectively incorporating microelectronic functions in minimal space.[5]

Figure 1: The smart sensor ecosystem[8]

| Physical environment | Smart sensors | Transmission standards | Secure gateway/ controller device | Centralized platforms |

Wi-Fi

Bluetooth

Near field communication (NFC)

Radio frequency identification (RFID)

Zigbee

Local area network (LAN)

External/central database

Cloud

Other innovations—such as micro-sensor implants and biodegradable sensors—have made smart sensors more dynamic and improved their business cases.[6] New wireless technologies are offering connectivity solutions that are more scalable and tailored than traditional wireless networks, which are designed for higher bandwidth, larger volume data devices. Low-power wide area networks (LPWAN), for example, have reduced cost, power consumption, and range issues for smart sensor usage.[7]

Extracting insights from sensor-created data is getting easier as analytics tools continue to improve. Handling and storing large, complex data sets is becoming more manageable through platforms such as Apache Hadoop. Tools such as complex event processing (CEP) enable processing and analysis of data on a real-time or a near-real-time basis, driving timely decision making and action. Algorithms continue to advance, expanding the capability to predict and prescribe courses of action.

Smart sensors in the supply chain
Integrating smart sensors throughout the supply chain can decrease operating costs, increase asset efficiency, improve demand planning, and provide critical insight into customer behavior. As centralized platforms and communication networks continue to evolve for the purposes of IoT devices, companies should consider the variety of smart sensors available (see figure 2) and determine how to better sensor-enable their supply chains from end to end.
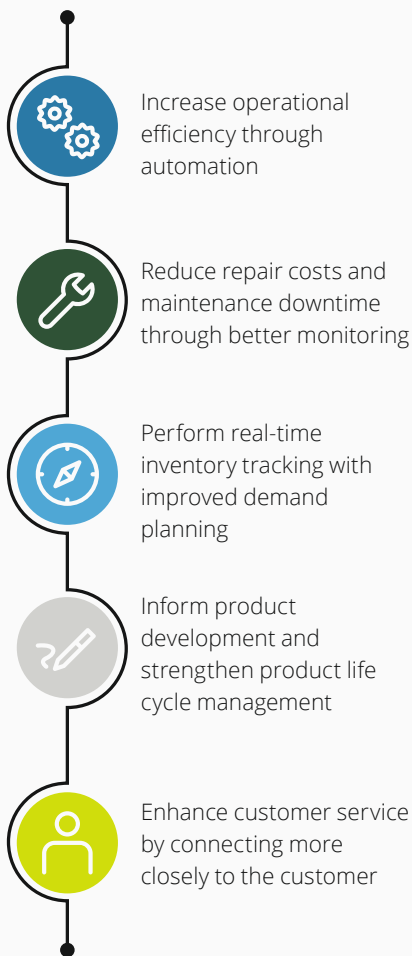
Figure 2: Types of smart sensors[2,3]

Type	Definition	Example
Acoustic	Recognize audio vibration or frequency to determine activity, location, intensity	Piezo microphones, electret microphones, condenser microphones
Chemical	Measure fluid composition and concentration of biological/chemical compounds	MEMS technology, fuel cell
Electrical	Identify and examine changes or disruptions in electrical or magnetic signals based upon environmental inputs or conditions	Voltage, current, power
Environmental	Monitor and assess deviations in physical state, conditions, or surroundings	Temperature, humidity, color, moisture, light, pressure, liquid flow, air flow, heat, surface temperature
Image	Convert light waves into electrical signals to constitute a digital, optical form for visible condition monitoring	Infrared, ultraviolet (UV), visible spectrum camera
Motion and force	Measure static and dynamic objects to determine the amount, type, and rate of change to physical properties	Proximity (ultrasonic/acoustic, infrared), strain/weight, vibration, accelerometers, shock accelerometers, gyroscopic, position, motion, magnetic field, rotational
Touch	Detect body capacitance during physical contact between objects	Capacitive touch, resistive touch

Benefits of smart sensors in the supply chain

Value drivers for smart sensors

Smart sensors increase the level of automated collection and processing of data and broaden management visibility across the supply chain to help companies reduce operating costs, improve asset efficiency, and generate incremental revenue.

Primary potential benefits

Increase operational efficiency through automation

Reduce repair costs and maintenance downtime through better monitoring

Perform real-time inventory tracking with improved demand planning

Inform product development and strengthen product life cycle management

Enhance customer service by connecting more closely to the customer

Operational efficiencies

Smart sensors introduce operational efficiencies that can help reduce labor, logistics, and quality control costs. Processes like inventory counting and materials sorting have become more automated with the assistance of smart sensors, thus helping to improve the productivity of human labor.

Sensor-enabled labor monitoring also helps reduce idle workforce by optimizing assignments. Likewise, autonomous driving enabling sensors can help reduce transportation costs through dynamic routing and improved safety. Smart sensors can also identify root errors in manufacturing and drive process enhancements, thereby maximizing production quality.[9]

Assembly lines that use wearables during quality inspection are able to send their photos to design engineers in real time through smart sensor technology. This closes the physical-digital loop in minutes—not hours or days—and allows engineers to identify the root cause of manufacturing issues at the time of assembly.[10]

Asset management

Companies that have integrated smart sensors in their manufacturing operations have achieved competitive advantage through improved asset management and predictive maintenance of industrial machinery. At Harley-Davidson's production facility, for example, every asset is connected, allowing management to track each step of production in real time in a performance management system and monitor critical equipment to proactively address potential interruptions.[11]

Secondary potential benefits

- New revenue channels through data brokering of connected products

- Better measure of the true cost of operations as indirect costs become more quantifiable

- Dynamic discounting from real-time inventory data and competitive pricing information

Real-time inventory tracking

RFID sensors, which allow for touch-free identification and tracking of items, have transformed traditional inventory management. RFID enables a more automated approach that can offer increased accuracy and real-time inventory tracking at a very low cost.[12]

These improvements allow for more traceability of inventory, potentially reducing the risk of inventory shrinkage or loss.

More reliable and current information can also strengthen demand-planning capabilities, potentially reducing out-of-stock and overstock situations. Moreover, advancements in smart sensor technology have generated savings from inventory theft protection and reduced spoilage.

Smart sensors also have more flexible distribution models. By providing customers multiple options in the purchasing process through real-time information flow, smart sensors enable omnichannel retailing. Products and packaging embedded with smart sensors make automatic reorders and refills possible. Likewise, connected appliances trigger sales at the point of consumption, such as grocery orders from the refrigerator.[13]

Product design

Connected products also offer insights into customer behaviors and preferences, allowing for more responsive product development. Their data can seamlessly feed into product life cycle management systems to stimulate innovation and accelerate speed to market on product updates.[14] Product developers are then able to optimize R&D spend and minimize risk of overengineering.

Customer service

By bringing the company closer to its consumers, smart sensors can help forge unique relationships. The company will likely become better equipped to react to customer demands and respond to critical events like food contamination. Real-time product usage data from embedded smart sensors could also improve companies' after-sale service offerings by allowing them to anticipate future problems, such as part failures.

This transparency goes two ways. Customers now have added visibility and can track products throughout the supply chain. Further, smart sensors allow for a disintermediated distribution channel and therefore a more fluid exchange between the customer and the supplier. Tesla, for example, relies on smart sensors to perform remote diagnostics and software upgrades, thereby cutting out traditional third-party service networks and deepening the relationship with customers.[15]

Case study: Ericsson's connected vessel[16]

Accounting for 80 percent of global trade, maritime shipping represents a critical component of international supply chain networks. The isolated nature of cargo ships, however, presents supply chain fragmentation challenges for the industry.

With the help of smart sensors and satellite communication, one communication company, Ericsson, has developed a solution to this challenge. Through ongoing sensor monitoring, stakeholders receive real-time data around vessel position and cargo container status to finally close the loop in the industry's supply chain logistics.

This end-to-end connected vessel introduces the following benefits:

- Location and movement data that provides logistics to a fleet management system similar to that of on-road shipping trucks

- An integrated supply chain system that enables shipping companies and producers to make informed decisions

- Software-based route planning that improves fuel efficiency and increases productivity

- Temperature data on refrigerated cargo to help recipients prepare in advance

- Sea-to-shore connectivity for crew to communicate

Criteria for evaluation and adoption

Operational considerations

A smart sensor strategy has the ability to disrupt current operating models and transform a company's supply chain. Success in this journey starts with asking the right questions in the following areas to create an understanding of a company's unique position and an awareness of how smart sensors can be employed.

Company profile

Several company attributes—strategy, business model, finances—play a critical role in the choices a company must make about smart sensor deployment. Key considerations include:

- How can smart sensor integration support your supply chain strategy?

- What challenges in data collection and aggregation do you currently face? How can automated data generation and edge computing support improvements?

- Are the financial and operational goals for the supply chain clearly defined?

Functional expertise and readiness

Smart sensor integration requires a high level of expertise to ensure interoperability. Moreover, extracting the full benefits of smart sensor data requires functional readiness to internalize the information and put the insights to work. Key considerations include:

- Are your current IT and data management resources capable of effectively integrating and managing a smart sensor ecosystem?

- What analytics capabilities exist to create insights from data?

- How is technology being used when making data-led decisions today?

Security and risk

Adding sensors to the supply chain could potentially create hundreds, if not thousands, of new surfaces for cyberattacks. Deployment of sensors across the supply chain requires heightened awareness of vulnerability and an intense focus on protecting systems. Key considerations include:

- Are you capable of defending against the types of cyberattack vulnerabilities introduced by smart sensors?

- How well do you know and understand your current data?

- How will your data governance need to be amended to include smart sensor information?

Investment

Though technology advances are driving down the cost of smart sensors, building the technology stack to enable a smart sensor ecosystem requires significant investment in product software and hardware, security tools, networking, storage, and systems integration. Key considerations include:

- What additions to your current IT infrastructure will be required to support a smart sensor ecosystem? Should you build these additions internally or outsource?

- How should you be structured to support longer-term growth and agility in the face of continuous technology advances?

- Are there sensors or connected devices already being used today? If so, how are they being integrated?

- What standardization and governance requirements will be needed for enterprise-wide alignment?

- Is there sufficient talent to support smart sensor installation, maintenance, and management?

Operating environments and locations

Identifying how and where the sensors will operate can provide valuable understanding of the type of sensors required, the infrastructure needed to support smart sensors, and the variety of supply chain insights to be gained. Key considerations include:
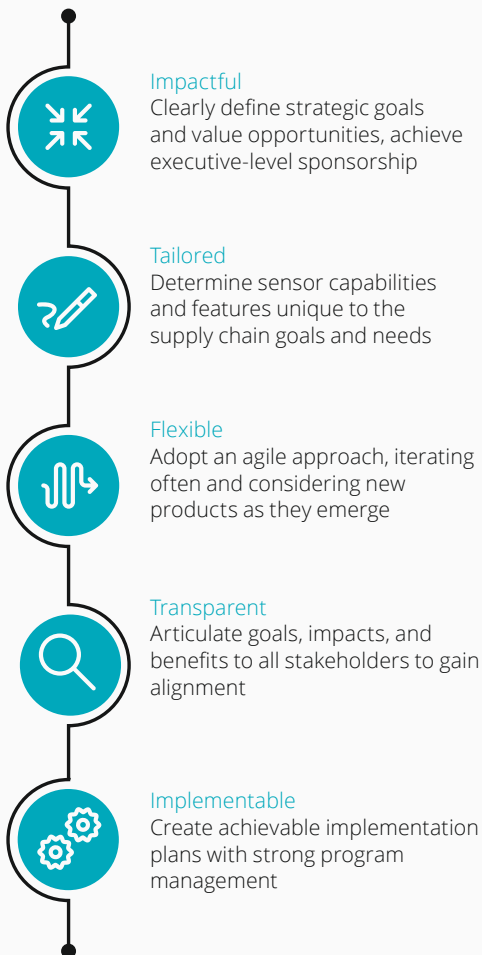
- How do current environmental conditions impact your supply chain?

- What type of capital assets do you own and how can they be smart sensor enabled?

- Are your supply chain resources concentrated in one area or are they distributed nationally or globally?

Framework for decision making

Smart sensor success factors

Yielding the full benefits of smart sensors requires an approach that is founded on broader ecosystem integration and is oriented toward achieving clearly defined analytics-driven objectives. This approach also requires decisions that are specific to the business, industry, and circumstances.

Impactful
Clearly define strategic goals and value opportunities, achieve executive-level sponsorship

Tailored
Determine sensor capabilities and features unique to the supply chain goals and needs

Flexible
Adopt an agile approach, iterating often and considering new products as they emerge

Transparent
Articulate goals, impacts, and benefits to all stakeholders to gain alignment

Implementable
Create achievable implementation plans with strong program management

Investment impact metrics

Companies should consider their supply chain goals and identify the appropriate level of investment required to get started. Many organizations can and should start small, using their business objectives to prioritize and pursue smart sensor pilots from which they can quickly learn. Organizations capable of larger implementations should deeply investigate and detail their goals to create clear priorities and a well-defined road map.

Smart sensor procurement

Smart sensor procurement decisions should strongly consider device compatibility with current and emerging systems. Successful deployment is contingent on the ability to integrate with both legacy ecosystems as well as innovative new IoT platforms, such as GE Predix and Uptake. Procurement decisions should also consider tradeoffs regarding purchase models and cost.

Direct purchase

Organizations can purchase smart sensors directly and self-deploy them throughout the supply chain. These sensors can be off-the-shelf or tailored solutions. Purchasing sensors directly will likely require additional investment in the technologies, infrastructure, and skills to develop the technology stack to support. This in-house approach provides the advantage of greater control over sensor features and data, as well as a learning curve that the company can leverage in future developments.

Sensing as a service

Smart sensors can also be deployed through a Software as a Service (SaaS) model, leasing the equipment and outsourcing data capture and management. This model generally provides a customized solution for the buyer and reduces the time, difficulty, and up-front cost associated with building a smart sensor ecosystem; however, companies may lose some influence over sensor features and uses. Furthermore, this service-based model can result in surrendering some ecosystem value to partners.

Service-based models are growing and becoming more diverse.[17] In addition to solutions-based offerings, providers are offering a la carte options as well (e.g., asset-only services).

Pricing factors

Sensor pricing ranges widely depending on capabilities and complexity. While highly sophisticated sensors can cost hundreds—if not thousands—of dollars, less complex devices are currently available for as low as $20.[4,18] Technology advances and increasing market competition are perpetually driving down prices. Commoditization of smart sensors will likely continue to exert downward pressure on pricing and make deployments more practical and feasible in the near term.

Key levers for smart sensors in your supply chain

Supply chain applications

Significant opportunities exist for smart sensor implementation in each stage of the supply chain.

| 01 Develop | 02 Plan | 03 Source | 04 Make | 05 Deliver | 06 Support |
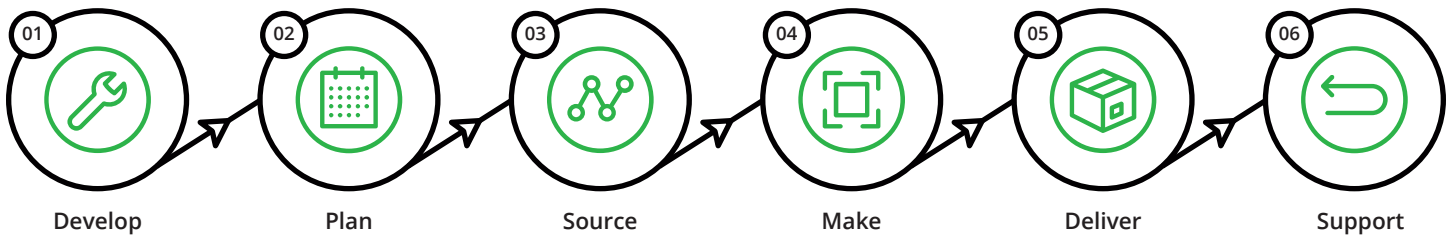
Develop: High volumes of usage data from connected products identify performance criteria and conditions that lead to enhanced product design and development. The ability to share information in real time also allows industry partners to actively collaborate with one another on shared prototypes.

Plan: Real-time inventory tracking from smart sensors improves inventory and supply planning.

Source: A well-functioning digital supply chain better identifies substitute materials and helps procure from lower-cost sources by leveraging the data revealed by smart sensors. Better transparency and traceability of raw material flow also helps ensure accurate and consistent supply.

Make: Manufacturing asset utilization increases as a result of improved monitoring and predictive maintenance of machinery from a fully connected production facility. Inbound material management improves through more dynamic management of dock deliveries.

Deliver: Smart-sensor-enabled, real-time inventory tracking helps optimize warehouse throughput, improve order management for perfect order fulfillment, and monitor deliveries. This technology also makes it easier for companies to sell the same products in-store and online, thus enabling a more flexible distribution model.

Support: Connected products can enable aftermarket sales and service opportunities by capturing and communicating impending maintenance needs.

These are all examples of ways in which smart sensors are improving supply chains today; however, they represent only a few of the many opportunities for cost reduction and value creation.

Motivation for action

The time for companies to assess their supply chains for piloting smart sensors is now. Connecting devices with smart sensors can provide managers insights into all phases of the supply chain and therefore drive efficiencies, reduce costs, and introduce new revenue opportunities.

Smart sensors have the potential to improve supply chains end to end

- Replace manual with automated processes and thus drive added efficiency and reduced labor costs

- Provide asset performance and predictive maintenance capabilities

- Introduce real-time inventory tracking to improve demand planning

- Offer data around customer behavior to inform product development and accelerate speed to market

- Enable closer connection to the customer for better service offerings

Key Deloitte contacts for smart sensors and supply chain management

Joseph Fitzgerald
Principal, Supply Chain &
Manufacturing Operations
Supply Chain Innovation
Deloitte Consulting LLP
+1 415 519 2115
josfitzgerald@deloitte.com

Adam Mussomeli
Principal, Supply Chain &
Manufacturing Operations
Consumer & Industrial Products
Deloitte Consulting LLP
+1 203 905 2646
amussomeli@deloitte.com

Andrew Daecher
Principal, Deloitte Digital IoT
Deloitte Consulting LLP
+1 415 783 6525
adaecher@deloitte.com

Mahesh Chandramouli
Senior Manager, Deloitte Digital IoT
Deloitte Consulting LLP
+1 214 840 1559
mchandramouli@deloitte.com

Endnotes

1. Deloitte University Press, *2016 Tech Trends*.

2. Raynor, Michael E. and Cotteleer, Mark J, "The more things change: Value creation, value capture, and the Internet of Things," Deloitte Review 17, July 27, 2015, http://dupress.com/articles/value-creation-value-capture-internet-of-things.

3. Deloitte University Press, *Inside the Internet of Things*, 2015.

4. "Smart Sensor Market Expected to Reach $60 Billion, by 2022, Globally," Sensors Online, 20 January 2017, http://www.sensorsmag.com/components/smart-sensor-market-expected-to-reach-60-billion-by-2022-globally.

5. Yurish, Sergey Y. and Gomes, Maria Teresa S.R. (2003), *Smart Sensors and MEMS*, Kluwer Academic Publishers.

6. http://government-2020.dupress.com/driver/sensor-technology/.

7. ABI Research, *Best Fit Use Cases for LPWANs*, August 2016.

8. http://engineering.nyu.edu/gk12/amps-cbri/pdf/Intro%20to%20Sensors.pdf.

9. Deloitte Analysis.

10. Riley, Sean, "Wearables in the Warehouse," Manufacturing Business Technology, February 17, 2016, https://www.mbtmag.com/article/2016/02/wearables-warehouse.

11. O'Connor, Mary Catherine, "Bringing Smart Technology to Old Factories Can Be Industrial-Size Challenge," Wall Street Journal June 7, 2016, https://www.wsj.com/articles/bringing-smart-technology-to-old-factories-can-be-industrial-size-challenge-1465351322.

12. "40% Warehouse Labor Costs Reductions with RFID," Advance Mobile Group, December 17, 2014, http://www.advancedmobilegroup.com/blog/how-does-modern-rfid-technology-improve-warehouse-performance.

13. Bohn, Dieter, "Samsung's New Fridge Can Order Fresh Direct Groceries from its Humongous Touchscreen," The Verge 2016, http://www.theverge.com/2016/1/5/10708380/samsung-family-hub-fridge-mastercard-app-groceries-ces-2016.

14. Martin, Jean-Francois, "How IoT Will Transform Product Lifecycle Management," mnubo 2016, http://mnubo.com/product-lifecycle-management-connected-object/.

15. Brisbourne, Alex, "Tesla's Over-the-Air Fix: Best Example of the Internet of Things?", Wired 2014, https://www.wired.com/insights/2014/02/teslas-air-fix-best-example-yet-internet-things/.

16. "IoT Case Studies: Companies Leading the Connected Economy," AIG 2016, https://www.aig.com/content/dam/aig/america-canada/us/documents/brochure/iot-case-studies-companies-leading-the-connected-economy-digital-report.pdf.

17. Gaddis, Ben, "How Sensors will Revolutionize Service Businesses," Wired 2016, https://www.wired.com/insights/2013/05/how-sensors-will-revolutionize-service-businesses/.

18. Miller, Ron, "Cheaper Sensors will Fuel the Age of Smart Everything," Tech Crunch, 10 March 2015, https://techcrunch.com/2015/03/10/cheaper-sensors-will-fuel-the-age-of-smart-everything/.

Deloitte.