Industry 4.0

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Executive summary

We are at the beginning of the fourth industrial revolution. The most commonly used terms to describe this development, which is rapidly changing the industrial landscape, are Industry 4.0, smart manufacturing, the Internet of Things, cyber-physical systems and digital transformation. The Industry 4.0 concept encompasses the digitalization of the horizontal and vertical value chain, innovation in products and services and the creation of new business models. The key business drivers of this transformation include improving customer experience, increasing speed to market and reducing costs (see figure 1).

To reap the benefits of this revolution, leaders of industrial enterprises have Industry 4.0 at the top of their agenda. However, implementing an Industry 4.0 production environment will be an incremental journey over several years that will include modernizing legacy systems. Once undertaken, the possibilities of applying Industry 4.0 concepts and technology are unlimited.

In this paper, we will answer the questions often asked by our clients:
- What is Industry 4.0?
- Why does Industry 4.0 belong on the C-level agenda?
- What are the business benefits?
- What are the challenges?
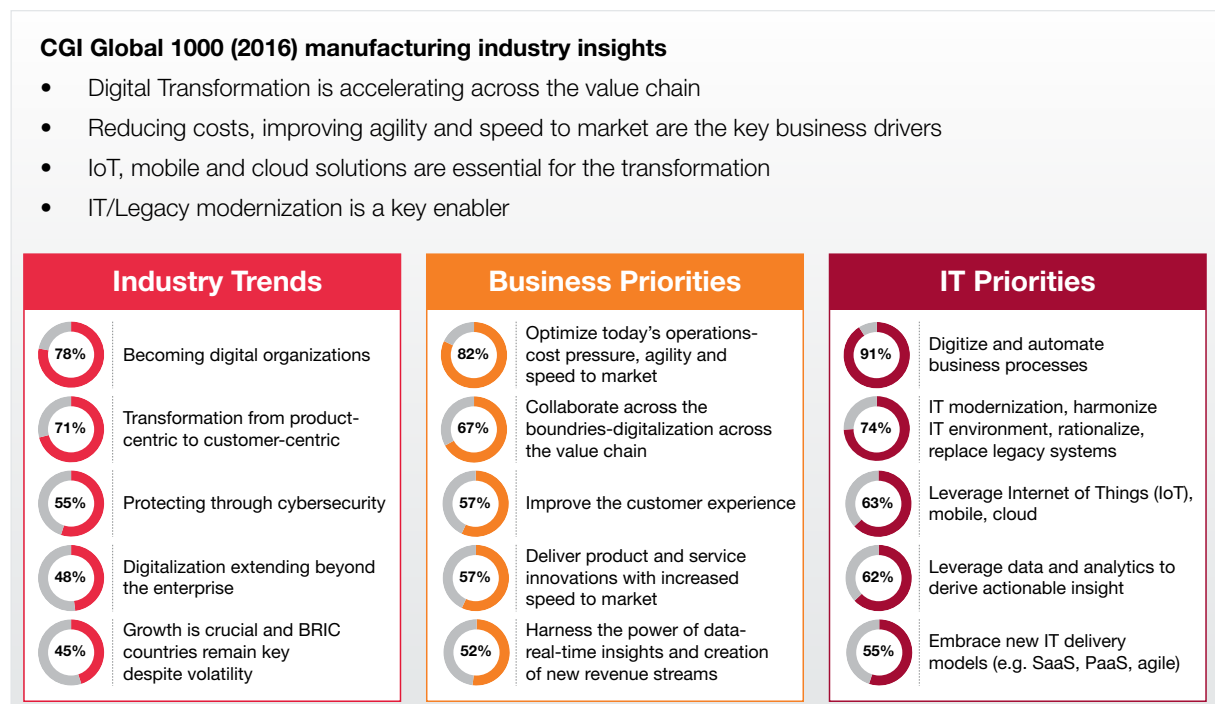- How do businesses implement this approach?

CGI Global 1000 (2016) manufacturing industry insights
- Digital Transformation is accelerating across the value chain
- Reducing costs, improving agility and speed to market are the key business drivers
- IoT, mobile and cloud solutions are essential for the transformation
- IT/Legacy modernization is a key enabler

Industry Trends	Business Priorities	IT Priorities
78% Becoming digital organizations	82% Optimize today's operations-cost pressure, agility and speed to market	91% Digitize and automate business processes
71% Transformation from product-centric to customer-centric	67% Collaborate across the boundries-digitalization across the value chain	74% IT modernization, harmonize IT environment, rationalize, replace legacy systems
55% Protecting through cybersecurity	57% Improve the customer experience	63% Leverage Internet of Things (IoT), mobile, cloud
48% Digitalization extending beyond the enterprise	57% Deliver product and service innovations with increased speed to market	62% Leverage data and analytics to derive actionable insight
45% Growth is crucial and BRIC countries remain key despite volatility	52% Harness the power of data-real-time insights and creation of new revenue streams	55% Embrace new IT delivery models (e.g. SaaS, PaaS, agile)

Figure 1: CGI Global 1000[1] (2016) manufacturing industry insights

[1] The annual CGI Global 1000 outlook brings together the findings, insights and CGI's point of view on the strategic topics that emerged from face-to-face conversations conducted with business and technology executives in commercial and government organizations. In 2016, CGI consultants interviewed more than 1,000 executives in 10 industries and 20 countries.

Introduction

Our physical world has become hyper connected and is now rapidly being augmented with a layer of "smartness." The fourth industrial revolution—like the ones that came before—is driven by new technologies. (Figure 2).
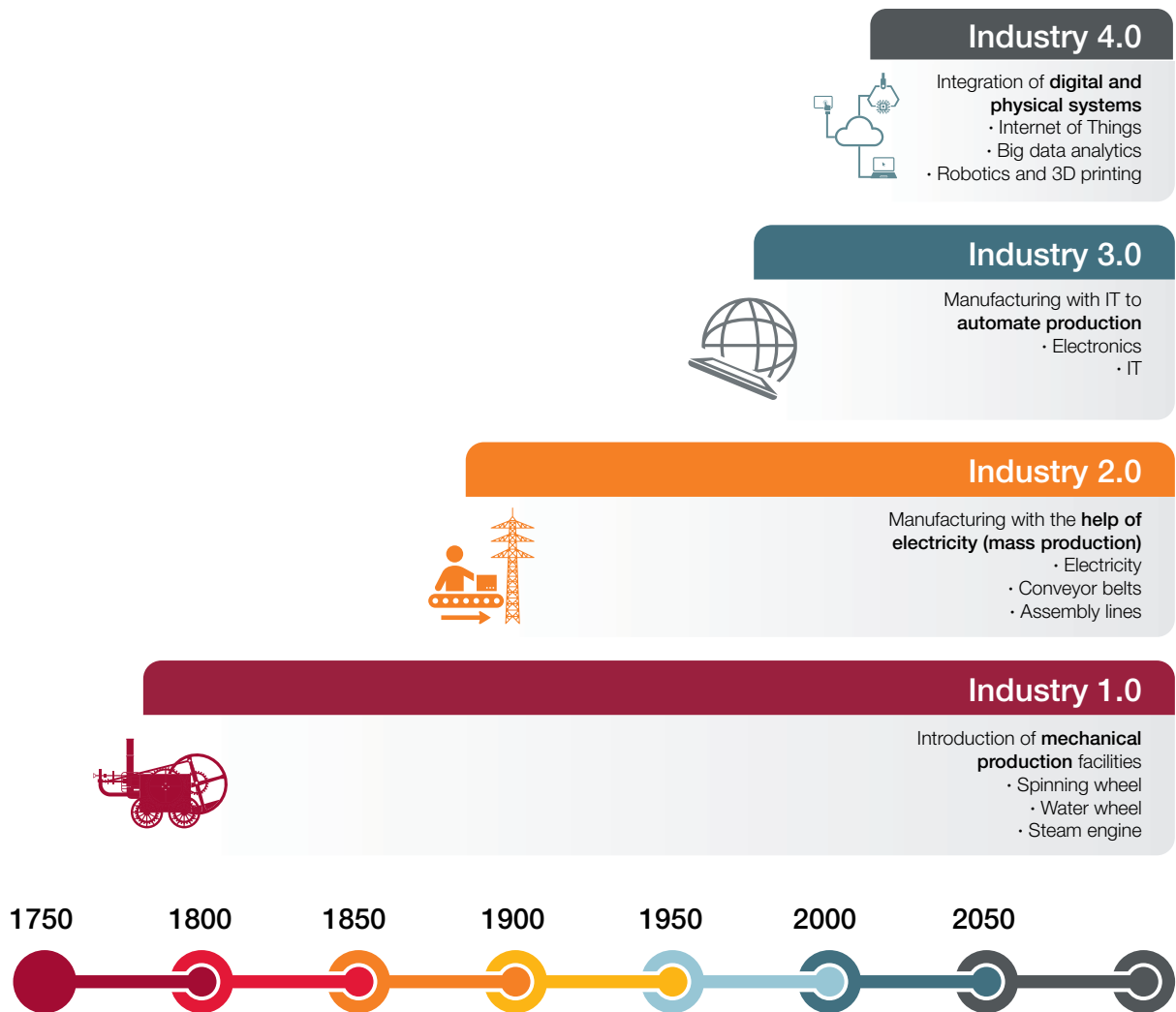

Industry 4.0

Integration of **digital and physical systems**
· Internet of Things
· Big data analytics
· Robotics and 3D printing

Industry 3.0

Manufacturing with IT to **automate production**
· Electronics
· IT

Industry 2.0

Manufacturing with the **help of electricity (mass production)**
· Electricity
· Conveyor belts
· Assembly lines

Industry 1.0

Introduction of **mechanical production** facilities
· Spinning wheel
· Water wheel
· Steam engine

1750   1800   1850   1900   1950   2000   2050

Figure 2: Industrial revolutions have always been driven by innovations in technology.

Industry 4.0 is enabled by technologies that integrate the digital and real worlds, such as:

- The Internet of Things (IoT): Connecting more and more systems, devices, sensors, assets and people through networks ranging from wireless, low-power wide-area networks to wired high-capacity networks
- Mobile solutions: Including smartphones, tablets, wearable sensors and smart glasses
- Cloud computing: Including low-cost processing and data storage solutions
- Cyber-physical systems (CPS): Monitoring and controlling physical processes using sensors, actuators and processors, based on digital models of the physical world
- Big data analytics and business intelligence: Turning data into actionable insights, which include early warning algorithms, predictive models, decision support, workflows and dashboards
- Advanced manufacturing technologies: Including robotics and 3D printing

New technologies have never been more abundant or affordable. At the same time, the capability to collect, distribute, share and analyze information to make decisions based on real-time data and predictive analytics, and create new business value has improved considerably. This is evident from the significant drop in sensor, bandwidth and processing costs in the last 10 years[2].

> Sensors, bandwidth and processing costs have dropped dramatically in the last decade:
>
> - Sensor prices have dropped to an average of 60 cents.
> - The cost of bandwidth has decreased by a factor of nearly 40 times.
> - Processing costs have declined almost 60 times.

Today, in the virtual world, new models can be used to simulate and analyze products and processes from the physical world. In product development, these models can be used for product optimization and to operate and control the manufacturing process. In business, these models can even be used to support business decisions.

[2] Goldman Sachs. "Internet of Things: Making sense of the next mega trend." 2014. Accessed November 28, 2016. http://www.goldmansachs.com/our-thinking/outlook/internet-of-things/iot-report.pdf

Industry 4.0: Why should it be on the C-level agenda?

The world is evolving more rapidly than ever before. As the adoption of digital technologies continues to move at a fast pace, organizations are seeking to rapidly transform. Moreover, a new economic order is emerging, where established manufacturers have to deal with both large digital organizations and innovative start-ups—both determined to build new revenue models.

New technologies, new products and services and new business models can be disruptive. In this scenario, adopting Industry 4.0 principles becomes a necessity, and tomorrow's leaders need to be prepared to embrace a different corporate structure. In this new economic order, Industry 4.0 will transform businesses in several ways:

- **Corporate strategy.** Industry 4.0 solutions will change the way companies operate. They will impact the product and service portfolio of companies. Today, smart products and services need to be developed, but tomorrow new business models will become necessary. In addition, start-ups with disruptive value propositions will enter the market. Under these conditions, implementing Industry 4.0 will require C-level commitment. Companies will need to understand the impact of digital transformation throughout their business.

- **Supply chain management, operations management and product life cycle management.** Digitalization is already making it easier for companies to collaborate. Cloud-based solutions are enabling companies to share data among customers, suppliers and other supply chain partners. However, a connected demand-driven supply chain cannot be achieved if departments and companies operate in silos. Integration of operations technology (OT) and information technology (IT) is required to connect process control, operations management and business planning. Organizations will also need digital product models for end-to-end product life cycle management.

- **Investment.** Industry 4.0 will have a big impact on the IT landscape. Digitalization will move from being an innovative trend to becoming a core competency[3]. The insights from the 2016 CGI Global 1000 outlook[4] reveal that manufacturing organizations want to decrease the cost of running legacy systems and processes, and increase investments in digital transformation (see figure 1). However, they are struggling to change the mix to fund transformation, as they need to run their current business, while transforming to Industry 4.0. In their efforts to accelerate business transformation, manufacturers are accelerating automation and digitization. While in 2015, only half the manufacturing executives interviewed cited digitalization and automation of business processes as a top IT priority, in 2016 more than 90% are investing in these areas in order to remain competitive and reduce operational costs (see figure 3). In this environment, the board of directors will need to make strategic investment decisions, align the IT investment portfolio with business priorities and maximize return on investment. In addition, CIOs will have to lead businesses in applying technology to enable innovation and advance business objectives.

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[3] "Keeping up versus stepping up." CGI.com. Accessed November 28, 2016. https://www.cgi.com/sites/default/files/white-papers/keeping-up-versus-stepping-up_white-paper.pdf

[4] In 2016 as part of CGI Global 1000 outlook, CGI conducted 87 in-person interviews with business and IT executives in manufacturing organizations across 13 countries to gain insights on top industry trends and their business and IT priorities and plans.
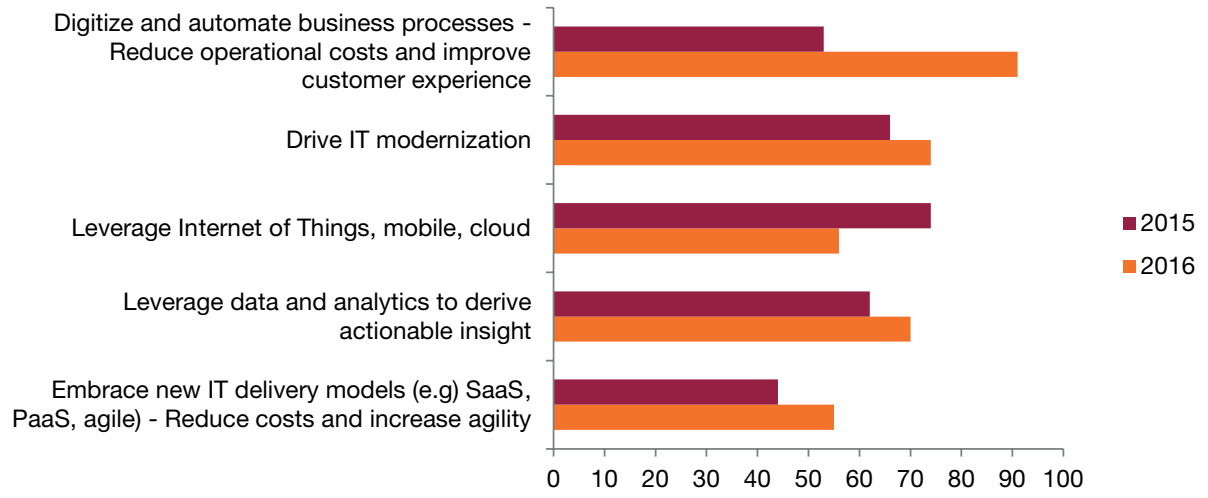
Figure 3: CGI Global 1000 (2016) - Manufacturing IT priorities

Industry 4.0: What are the business benefits?

The possibilities of applying Industry 4.0 technology are unlimited.

A digitally-integrated and intelligent supply chain enables an unprecedented level of collaboration and real-time visibility across the supply chain to help address rising customer expectations
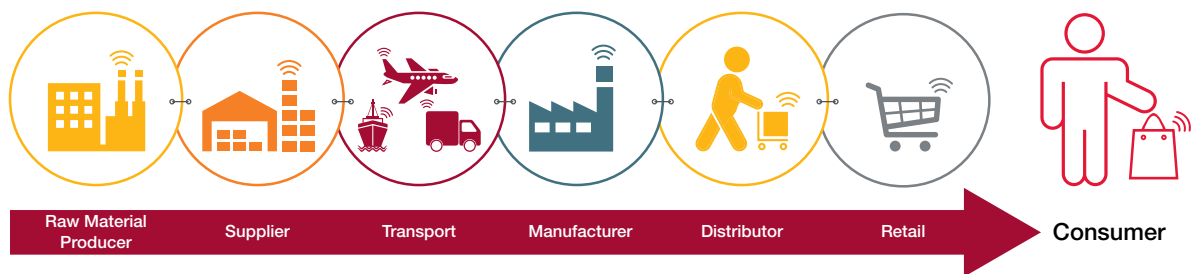
Raw Material Producer → Supplier → Transport → Manufacturer → Distributor → Retail → Consumer

Figure 4: Imagine the real-time connected supply chain

Imagine a real-time connected supply chain. What if all the participants in the supply chain shared data from their production sites, vehicles, warehouses and databases in real time? What if you used real-time points of sale and inventory data to understand the state of your business? Would you be better equipped to accommodate critical orders and meet customer expectations with faster, more accurate shipping and handling?

Imagine connected vehicles, containers and pallets. What if your company tracked and controlled the condition and location of your products throughout the supply chain? Would this help your company improve inventory management and product quality? Would serialization help your company deal with fraud and counterfeit products?

Imagine connected smart production equipment. What if equipment settings were self-adjusted based on materials used, products being made and other ambient conditions? Is your company able to customize mass-produced products based on the needs of an individual customer? What if equipment could be monitored remotely and malfunctions predicted accurately?

Imagine connected mobile and wearable devices. What additional functionalities and services would your company deliver to customers? How would you improve worker safety?

Whatever your business, what if a fluid digital continuum could connect your departments, customers, suppliers, partners, production equipment and products throughout your product and services life cycles?

A digitally-integrated and intelligent value chain offers almost limitless possibilities. Industry 4.0 solutions improve operations efficiency, productivity, product quality, inventory management, asset utilization, time to market, agility, workplace safety and environmental sustainability.

Figure 5 identifies the main activities that are enabled by Industry 4.0 technologies.

Planning	Development	Marketing & Sales	Inbound Logistics	Production	Outbound Logistics	Maintenance & Services
Forecasting methods	Product Lifecycle Mngt (PLM)	Customer intelligence	Track and Trace products	Operational intelligence	Distribution planning	Maintenance, Repair and Overhaul (MRO)
Collaborative work	Connected products	Promotions	Smart containers	Advanced process control	Inventory management	Enterprise Asset Management (EAM)
Demand management	Collaborative engineering	Digital marketing	Serialization	Manufacturing Execution Systems	Warehouse management	Field services
Integrated enterprise mngt	Remote monitoring	eCommerce solutions	Just-in-time (JIT) logistics	Smart tools and machines	Transport management	Predictive maintenance
Safety stock optimization	Remote software update	Point-of-sale (POS) analytics	Supplier collaboration	Energy management	Track and Trace products	Mobile worforce management
	Collaborative engineering	User consumer experience	Inventory management	Predictive maintenance		Augmented reality
	3D product models	Secure payment systems		Quality management		Condition monitoring
	Process stimulation	Servitization		Tracking genealogy		Remote maintenance
				Smart packaging		

Figure 5: Industry 4.0 solutions by business function

Today, the most promising Industry 4.0 solutions are energy management and predictive maintenance, especially in combination with manufacturing execution systems (MES). This was visible at Hannover Messe, in April 2016, where condition monitoring, predictive maintenance and energy management were the most commonly shown use cases.

Predictive maintenance

Using sensors to determine when equipment needs to be serviced can prevent breakdowns and reduce routine maintenance costs

With in-built sensors connected to the Internet, it is possible to monitor production equipment remotely and in real time. This enables predictive maintenance, where analytical models can be applied to predict future areas of concern. In this case, recommendations can be sent to operations, maintenance and IT departments to address a breakdown, even before it occurs. By doing so, operating costs and capital costs can be reduced by facilitating proactive servicing and repair of equipment, thereby improving capacity utilization and productivity.

Together with Microsoft, CGI has developed an elevator maintenance solution for one of the world's leading elevator manufacturers, using the latest Internet of Things (IoT) technology. The company, which maintains more than 1.2 million elevators around the world, wanted to transition to a more proactive, predictive maintenance approach driven by real-time data. The solution extracts data from smart sensors on the elevator, generates valuable insight using analytics, and makes the information available to supervisors and service technicians via cloud-based dashboards. The system was implemented for a number of the company's elevators and has resulted in reducing elevator downtime and improving resource planning, cost forecasting and maintenance scheduling.

In this way, equipment manufacturers can use IoT technology to change their business model to a service model, provide ongoing maintenance under contract and guarantee a defined uptime for equipment. IoT technology enables real-time monitoring and remote service. In addition, performance data can be gathered to improve the design and reliability of the equipment, thereby reducing warranty costs. Once equipment is interconnected and managed through IoT, it is possible to improve asset utilization significantly.

According to research by McKinsey & Company[5], predictive maintenance using IoT can reduce maintenance costs of factory equipment by 10–40% and bring down equipment downtime by up to 50%.

[5] James Manyika, Michael Chui, Peter Bisson, Jonathan Woetzel, Richard Dobbs, Jacques Bughin, and Dan Aharon. " The Internet of Things: Mapping the value beyond the hype." McKinsey & Company. June 2015. Accessed January 31, 2017. http://www.mckinsey.com/business-functions/digital-mckinsey/our-insights/the-internet-of-things-the-value-of-digitizing-the-physical-world

Energy management

Managing energy consumption results in greener operations, lower energy costs, lesser unplanned downtime and more consistent quality

Manufacturers are increasingly pursuing a resource efficient and sustainable approach due to several economic, social and governmental pressures. In energy-intensive industries, energy costs form a significant part of the operation costs. In this scenario, the use of IoT and predictive analytics has an important role, as these technologies can reduce energy consumption and operating costs significantly.

In manufacturing organizations, metering does not reveal how energy is distributed across buildings, processes and equipment. Therefore, the first step towards developing a systematic approach to energy management and improving a company's competitive position lies in the increased visibility of energy consumption patterns.

CGI has worked extensively in this area, as we have built energy monitoring systems for clients in the chemical and food industries. Our insight into the use of energy saves millions of dollars in operating costs. For instance, CGI's energy monitoring system (EMS) for a global manufacturer of confectionery, pet food and other food products has been deployed in multiple factories—reporting on energy consumed by end-users, improving their energy efficiency and reducing energy consumption.

In our experience, energy consumption in a plant can be easily monitored through sensors in a facility and production equipment. Monitoring deviations from regular energy consumption can help to detect failing equipment. In addition, manufacturing execution systems (MES) capture relevant data, such as equipment settings, shifts and process parameters, providing insight into how energy is used in operations. Further, predictive analytics also provides manufacturers with insights that help in the implementation of energy programs.

According to research by McKinsey & Company[6], PWC[7] and Roland Berger[8], energy management using IoT can reduce factory energy costs by 10–30%.

[6] Ibid
[7] Dr. Reinhard Geissbauer, Simon Kuge, Stefan Schrauf, Volkmar Koch. "Industry 4.0: Opportunities and Challenges of the Industrial Internet." Strategy&. Accessed November 28, 2016. http://www.strategyand.pwc.com/reports/industry-4-0
[8] Marc Winterhoff. Stephan Keese, Christian Boehler, Christopher Hoyes. "Digital factories: The renaissance of the U.S. automotive industry". Roland Berger. Accessed November 28, 2016. https://www.rolandberger.com/publications/publication_pdf/roland_berger_tab_digital_factories_20160217.pdf.

Other areas of interest are supply chain management and inventory management. Industry 4.0 solutions can offer manufacturers a comprehensive view of the production process and provide real-time controls that facilitate an uninterrupted flow of finished products and avoid defects. Additional sensors can also be installed in plants to monitor process conditions with greater granularity, while models can be used to predict process capability and product quality. This helps organizations to monitor the end-to-end manufacturing process, address bottlenecks, reduce waste and energy costs, and remove operator intervention.

IoT can also improve inventory management by using weight or height detection sensors to enable condition-based automatic reordering, depending on actual stock quantities, instead of replenishment estimates. Furthermore, remote monitoring and sensing of toxic gas, oxygen and ozone levels inside plants can dramatically increase workplace safety[9].

Before starting with a new project, most companies look for the business case. Although quantifying business benefits for Industry 4.0 in general is not an exact science, one can look to recent research from multiple companies (The Smart Manufacturing Leadership Coalition[10], McKinsey & Company[11], PWC[12] and Roland Berger[13]) to derive expected benefits, including:
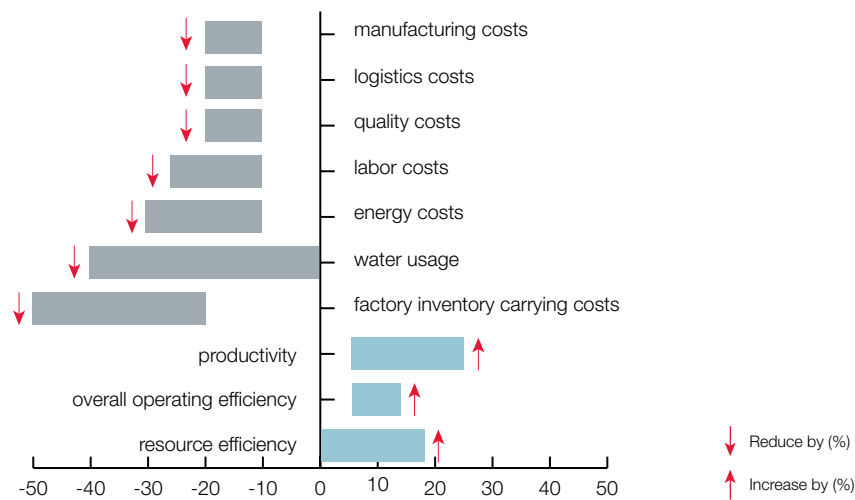
Figure 6: Improve operating efficiency

9   James Manyika, Michael Chui, Peter Bisson, Jonathan Woetzel, Richard Dobbs, Jacques Bughin, and Dan Aharon. " The Internet of Things: Mapping the value beyond the hype." McKinsey & Company. June 2015. Accessed January 31, 2017. http://www.mckinsey.com/business-functions/digital-mckinsey/our-insights/the-internet-of-things-the-value-of-digitizing-the-physical-world

10 "Economic Benefit". Smart Manufacturing Leadership Coalition. Accessed November 28, 2016. https://smartmanufacturingcoalition.org/economic-benefit

11 James Manyika, Michael Chui, Peter Bisson, Jonathan Woetzel, Richard Dobbs, Jacques Bughin, and Dan Aharon. "Internet of things: Mapping the value beyond the hype". McKinsey & Company. June 2015. Accessed November 28, 2016. http://www.mckinsey.com/business-functions/digital-mckinsey/our-insights/the-internet-of-things-the-value-of-digitizing-the-physical-world

12 Dr. Reinhard Geissbauer, Simon Kuge, Stefan Schrauf, Volkmar Koch. "Industry 4.0: Opportunities and Challenges of the Industrial Internet." Strategy &. Accessed November 28, 2016. http://www.strategyand.pwc.com/reports/industry-4-0

13 Marc Winterhoff. Stephan Keese, Christian Boehler, Christopher Hoyes. "Digital factories: The renaissance of the U.S. automotive industry". Roland Berger. Accessed November 28, 2016. https://www.rolandberger.com/publications/publication_pdf/roland_berger_tab_digital_factories_20160217.pdf.
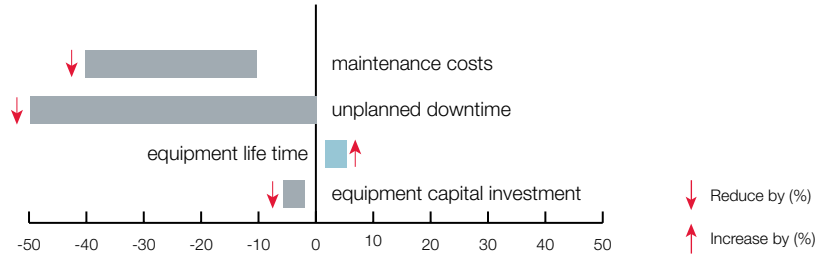
Figure 7: Improve asset management
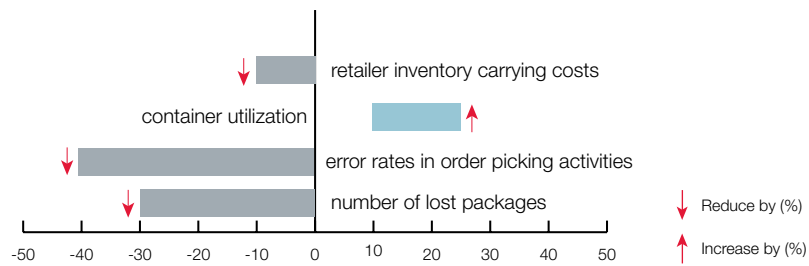

Figure 8: Improve safety

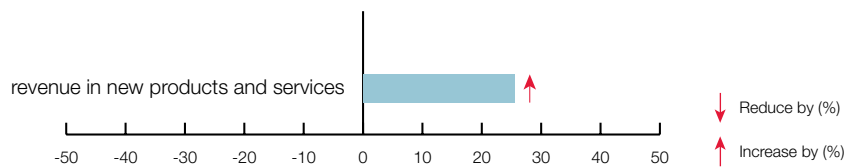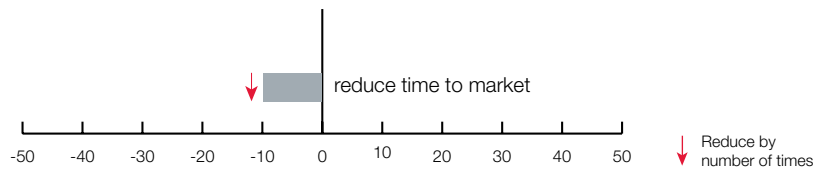Figure 9: Improve supply chain management

Figure 10: Improve revenue

Figure 11: Reduce time to market

Note: The figures in the above diagrams are only indicative and may vary among industries and companies.

Industry 4.0: What are the challenges?

Industry 4.0 comes with challenges. Today, manufacturers deal with huge quantities of information, both structured and unstructured, which reside in databases that are not always properly connected. To create business value and meet customer expectations in terms of innovation, personalization and speed to market, it is necessary to connect these silos and enable a single, unbroken collection of data that is woven throughout the supply chain. In order to achieve this, the following areas need to be addressed:

- **Awareness:** Many manufacturers are still unaware of the possibilities that Industry 4.0 technologies can offer[14] and company-specific business cases do not demonstrate this suitably.

- **People:** Introducing new business models, business processes, and connected products and services will transform the way employees perform everyday tasks. In order to deploy Industry 4.0 solutions, companies need new people and skills. Certain jobs like those of industrial workers will change or might even become redundant. Warehouse workers, for instance, are expected to be replaced by autonomous robots. New roles, such as "robot coordinator" and "data scientist", have been created, while routine and physically demanding jobs will disappear. Data scientists, for instance, collect and analyze data and apply their insights to improve manufacturing processes and products. Robot coordinators oversee robots on the shop floor, responding to malfunctions and carrying out maintenance tasks. Industrial workers have to adapt to new roles and work environments. Today, operators already monitor multiple machines and processes simultaneously, while service technicians are assisted by augmented-reality technology and remote guidance from experts offsite. Jobs will require more and more flexibility, IT competency, knowledge of manufacturing and analytical skills. In this scenario, where resistance to change is the main barrier, people will need to be motivated and trained to deliver new products, services and business processes.

- **Cybersecurity:** With digital factories and a digitally-connected value chain, traditional IT security is not enough to protect the business. To overlook this reality is to compromise the stability and security of the company. As companies innovate, the "attack surface area" or the enterprise area that is vulnerable, gets bigger. The challenge lies in understanding the potential cyber risk that innovation brings. A single plant shut down can cause production losses of millions of dollars each day. Therefore, cybersecurity risks must be mitigated. Industrial IoT devices must be highly secure by design, and securely integrated into existing automation and information system architectures. Since breaches are inevitable, detection

[14] Mathew Littlefield. "Smart Connected Operations: Capturing the Business Value of the Industrial IoT." LNS Research. 2015. Accessed November 28, 2016. http://www.lnsresearch.com/research-library/research-articles/-ebook-smart-connected-operations-capturing-the-business-value-of-the-industrial-iot

and response mechanisms have to be in place in the industrial control systems (ICS) area as well. This will build a necessary level of resilience for the company. In these circumstances, securing industrial control systems and ensuring cybersecurity cannot be understated. This can also help manufacturing organizations differentiate themselves from the competition.

- **Investments:** In order to implement Industry 4.0 solutions, considerable investments are required to create a robust and secure network infrastructure and upgrade or replace legacy systems. To justify these investments, benefits have to be unequivocally and reliably quantified.

- **Collaboration:** Today, no single vendor can deliver all the capabilities needed to implement Industry 4.0 solutions, as they are based on multiple technologies and devices that run on different networks. The delivery of Industry 4.0 solutions will be facilitated by an ecosystem of IT vendors, OT vendors, system integrators and emerging IoT startups. The critical success factor is close collaboration between the business, IT and OT.

- **Standardization:** Existing manufacturing standards are insufficient to fully enable Industry 4.0 and new technical, architectural and business standards are needed. As an increasing number of devices and systems that use proprietary communication protocols enter the market, data silos are formed, creating a complex network of connections between isolated data sources. Although multiple standardization bodies and industry consortia have published reference architectures and standards, there are no universal standards. This makes it tough for organizations to eliminate data silos. In fact, for years to come, the Industry 4.0 ecosystem will consist of multiple reference architectures, standards and protocols.

- **IT modernization:** Currently, industrial automation system deployments are a collection of proprietary technologies and networks. In the future, we will need to connect business planning and logistics solutions, manufacturing operations management solutions and industrial control systems, such as supervisory control and data acquisition (SCADA), distributed control system (DCS), programmable logic controller (PLC) and human-machine interface (HMI). Processes will not be controlled by a standard programmable logic controller (PLC) anymore, but by a service-oriented, decentralized control system consisting of distributed microcontrollers that communicate using Internet standards. Already, hybrid IT environments combining cloud and traditional IT delivery models are on the rise, as cloud computing continues to emerge as a key enabler of both digital transformation and operational efficiency.

Industry 4.0: How will it impact the IT and OT?

Creating an Industry 4.0 production environment will be an incremental journey over many years. For decades, the ISA 95 reference architecture has been used to describe the systems and processes used across the enterprise. We expect that Industry 4.0 will change the ISA 95 reference model. Devices, process control systems, manufacturing execution systems and ERP systems will also be connected to IoT platforms (see figure 12).
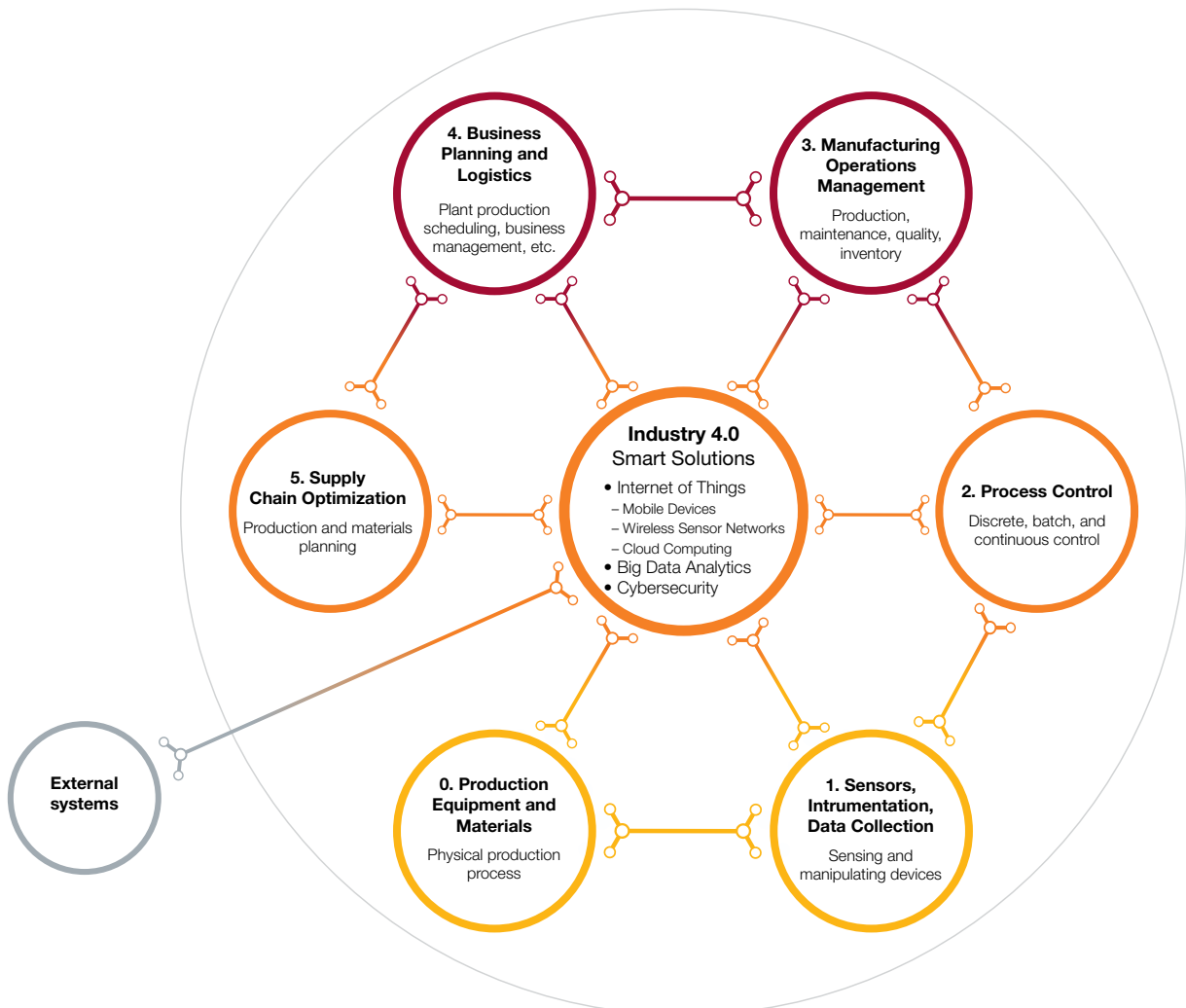

Figure 12: Enabling the digital enterprise by connecting legacy systems and leveraging Industry 4.0 solutions

Modernizing existing unconnected devices and systems will be critical to become more competitive.

Industry 4.0 enables shop floor (OT) and top floor (IT) integration by:
- Modernizing existing plants and assets by connecting existing IT and OT systems, sensors, devices, assets, products and materials with an IoT platform
- Creating new Industry 4.0 solutions that integrate data, people, workflows and legacy systems with solutions and services delivered via the cloud

Industry 4.0: How to implement this approach?

Developing successful Industry 4.0 solutions can be a complex task. Mikado, a pick-up sticks game is a good metaphor to illustrate the complexity involved and the vision required to implement Industry 4.0 solutions. In the game, to change the position of one stick, you need insight into the impact that it will have on the movement of the other sticks.

Figure 13: Mikado—what elements of your operating model will change?

Implementing Industry 4.0 technology successfully is similar. It requires a structured, holistic approach that is focused on increasing business value and reducing business risks. CGI's Digital Transformation Delivery Framework (see figure 14) offers a structured approach to manage interrelated changes in the operating model of an enterprise (products and services, organization, people, processes, applications and infrastructure). The framework adopts the following approach:

- First, a clear vision is needed on how Industry 4.0 impacts your business.
- Based on that vision, plans are made to shape future operations.
- Based on those plans, current operations are changed.
- Finally, the future mode of operation is delivered. This includes an effective approach for program management, stakeholder engagement, and benefits and risk management, in order to control the transformation and its outcome.
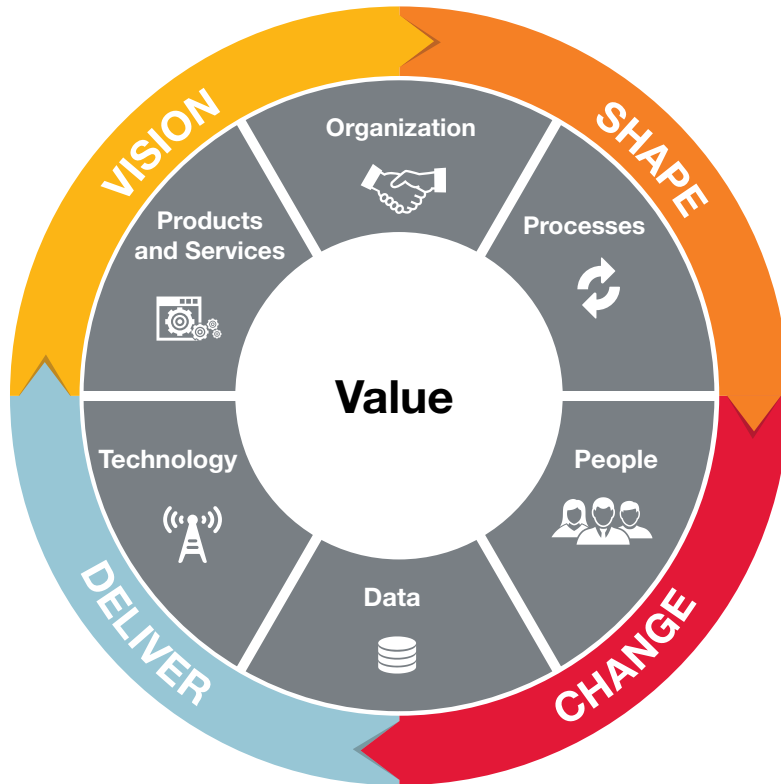
Figure 14: CGI's Digital Transformation Delivery Framework

The next step depends on your Industry 4.0 maturity level

The Industry 4.0 journey starts with the availability of data. Whether you are building new facilities or refurbishing an existing plant, production equipment, systems and sensors can generate large amounts of data on every aspect of the operation. This data has to be collected, aggregated, and analyzed to unlock its business value for Industry 4.0 solutions.

Deriving value from data largely depends on an organization's capability to collect, manage and analyze data. Today, while sensors and production systems can generate massive volumes of data, making sense of this data flood requires strong data management, storage and high-performance data analytics capabilities.

The roadmap for implementing Industry 4.0 depends on the digital capabilities of an organization. In our Industry 4.0 maturity model, we distinguish five maturity levels. These characteristics are shown in figure 15 and described below.

	Ignoring	Exploring	Standardizing	Adopting	Adapting
Leadership	Create awareness and discover the benefits	Build proof of concepts Collaborate with IT and OT vendors	Define/implement an Industry 4.0 strategy for the enterprise	Define/implement an Industry 4.0 strategy for the value chain	Create new (disruptive) products, services and business models
Data	Data silos	Share data between departments analyze, and obtain new insights	Share data across the enterprise Implement Master Data Management	Share data between companies Implement clear data ownership	Share data across the value chain Implement data quality as KPI
Technology	Technology silos Descriptive analysis	Connected devices and data sources Diagnostic analytics	IT modernization Application integration IoT platform	Apply secure open standards Predictive analytics	Xaas Prescriptive analytics
Security	Basic network protection	Ad hoc application and infrastructure protection	Enterprise-wide application and infrastructure protection	Identity-aware information protection	Adaptive and automated security control

Figure 15: Industry 4.0 characteristics based on maturity level

1. **Ignoring:** Business units and departments act as standalone entities, formulating their own strategies and work plans. They have their own systems and data silos that run parallel to each other. The focus is on the execution of tasks of the organizational unit. Data collection and analytics are used for reporting and answering the question "what happened?". There is basic network protection, as production equipment and systems are not connected to the Internet. The ability to move to the next maturity level depends on the awareness, interests, knowledge and capabilities of individuals.

2. **Exploring:** Business units and departments start to collaborate—sharing data, integrating applications and experimenting with new Industry 4.0 technologies. Data collection and analytics is used for understanding and answering the question "why did it happen?". The integration of OT and IT IoT platforms are used to collect and analyze data. The first projects are initiated by Industry 4.0 evangelists. Applications and infrastructure are provided with ad hoc cybersecurity safeguards.

3. **Standardizing:** Business units and functions collaborate across the enterprise. In addition, the organization defines an Industry 4.0 enterprise strategy, reference architecture, and

standards for data and end-to-end process automation. Production equipment and systems are connected to IoT platforms. Data collection and analytics are used for prediction, answering the question "what is likely to happen?". There is enterprise-wide application and infrastructure protection.

4. **Adopting:** This level is characterized by collaboration between enterprises across the business ecosystem. The organization defines an Industry 4.0 strategy and reference architecture for the business ecosystem. Data is shared in real time across company boundaries. As a result, real-time data collection and analytics are used in operations, answering the question "what is happening?". Applications built on IoT platforms provide additional services and predictive models are used to support decision making. There is identity-aware information protection.

5. **Adapting:** These companies are at the highest level of maturity and lead the business ecosystem. They introduce new and disruptive products, services and business models, which are based on automation of the value chain. Real-time data collection and analytics are used in operations to answer the question "how can we make it happen?". Prescriptive models are used to simulate and optimize the business. There is adaptive and automated security control.

The first step in the Industry 4.0 journey is making executives and business owners aware of the impact that Industry 4.0 can have on their business. They have to be aware of the benefits that Industry 4.0 technology can offer and understand the use cases, value of data and the importance of cybersecurity.

The next step is to identify, prioritize and pilot Industry 4.0 solutions for the most promising use cases that can help reduce operating costs. Reduction of operating costs makes your business more competitive and generates resources for other Industry 4.0 solutions. For each use case, proof of concepts must be built to explore suitability for the organization and gain experience. In order to obtain new insights and generate business value, devices and systems have to be connected to an IoT platform, and data has to be collected and analyzed. In this context, good collaboration with multiple vendors is essential.

Once you have explored and implemented several Industry 4.0 solutions, you will understand that defining and implementing an Industry 4.0 strategy is necessary to align different business functions. A key element of the Industry 4.0 strategy is IT modernization to remove any roadblocks. Another important activity is to define Industry 4.0 reference architecture.

The next level will be to share data across companies and make decisions regarding important activities such as data ownership and metadata management. It is also important to build predictive models to optimize business processes. Eventually, data quality key performance indicators are implemented across the supply chain and the business is optimized based on prescriptive models. New and disruptive, products, services and business models are created.

Conclusion

Industry 4.0 will change the entire manufacturing system, from the architecture and organizational structure to products, services and business models. The development and deployment of these solutions will be incremental and part of a long-term trend, but the opportunity is already here today.

Companies that fail to educate themselves on these new technologies and invest in pilot projects will lose their competitive advantage and miss the opportunity to lead the transformation that is currently sweeping across the manufacturing industry.

If you have not yet begun on this journey, you must start today.

About the authors

This white paper has been created by a team of senior experts at CGI who have more than 25 years of experience in the manufacturing industry, advising leading manufacturing organizations on their transformation and supporting complex transformations. In this paper, they share their deep understanding of manufacturing organizations' processes as well as their expertise in the latest technologies, software and methodologies for the digital century.

About CGI in Manufacturing

CGI is the partner and expert of choice for manufacturers in a wide range of sectors, including automotive, aerospace, high tech, mining, metals, pulp and paper, and chemicals. Our 2,800 supply chain experts help clients modernize legacy systems, optimize operations and digitize processes by driving cross-functional collaboration and data continuity across traditional silos and throughout the ecosystem. Our client-inspired business solutions enable them to drive down costs and increase productivity and agility to digitally transform and grow. As our manufacturing clients embark on their journey to Industry 4.0, we have the talent, scale and in-depth industry expertise to help them transform from product-centric to customer-centric businesses, bringing forth innovative strategies and technologies to enable their transformation end-to-end.

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