Capgemini Consulting

Industry 4.0 - The Capgemini Consulting View

Sharpening the Picture beyond the Hype


4.0

Contents

Executive Summary: The Capgemini Consulting Industry 4.0 Framework

The key promise of the Industry 4.0 concept is as striking as it is fascinating: we are about to witness a new industrial revolution, fueled by the advancement of digital technologies. The fusion of the physical and the virtual world into cyber-physical systems will have a disruptive impact on every business domain of manufacturing companies. Three years after the advent of Industry 4.0 as a concept it has now developed into a true hype in the manufacturing industry. Hardly any conference, think-tank or exhibition escapes the gravitational pull caused by the promise of a new industrial revolution.

Understanding the danger of the hype

First of all: we strongly believe in the concept of Industry 4.0! Digital technologies already have and will continue to have a disruptive impact on the manufacturing industry, leading to the fourth industrial revolution as outlined in previous studies by the Massachusetts Institute of Technology (MIT) and Capgemini Consulting[1].

However, there is an issue around the current hype: the idea of how Industry 4.0 should actually be addressed becomes increasingly fuzzy. It has emerged in our discussions with clients and partners that there is no common understanding of how the manufacturing business will change and how organizations need to transform. There is a risk that the hype around Industry 4.0 will bypass corporate reality. Nevertheless, the consequences for late-movers are most likely devastating: as in earlier industrial revolutions, organizations ignoring the need for change will be forced out of the market rapidly.

Sharpening the picture beyond the hype

Facing the industrial revolution ahead, manufacturing companies need to start developing a comprehensive vision of how they will run their business in the future. They are required to look beyond the hype and identify which specific opportunities and challenges arise from Industry 4.0. Building on that, manufacturing companies need to define a target picture and a transformation roadmap that outlines the journey with respect to the new world ahead. In order to provide guidance along this process, Capgemini Consulting has developed a framework structuring the key building blocks of Industry 4.0.

Enabling the revolution through digital technologies

The fourth industrial revolution is triggered by digital technologies that have a disruptive impact on manufacturing companies' business models, the way they operate and create customer value. It will be important to understand how to optimally leverage a smart combination of these technologies in terms of value creation in the digital age. Reflection is also needed on how to strengthen manufacturers' competiveness in a more complex environment of players from within and outside the classical manufacturing value chain. Leveraging the fusion of the physical and the virtual world into cyber-physical systems strongly requires a collectivity of technologies such as machine-to-machine communication, cloud computing and advanced analytics. Manufacturing companies need to develop a deep understanding of the technologies, thus unveiling opportunities and challenges to the way they run their business today.

Identifying the core value drivers

Succeeding in the next industrial era requires manufacturing companies to define and shape their core value drivers, enabled by digital technologies. Today the discussion around Industry 4.0 is mainly focused on driving operational efficiencies. *Smart Factories* and *Smart Supply Chains* will indeed entirely redefine our understanding of operational excellence.

However, there is a lot more to the Industry 4.0 scenario than a mere bottom-line perspective. Digital technologies will strongly affect the way companies innovate. The *Smart Innovation* and collaboration models of 'Industry 4.0' will yield *Smart Solutions* leveraging digital technologies to increase customer value. They will ultimately lead to completely new business models and service offerings.

Transforming corporate structures to Industry 4.0 readiness

Leveraging the Industry 4.0 core value drivers will require a comprehensive corporate transformation. First, the vast amount of data stored, transferred and processed in an Industry 4.0 scenario will require a next-level *Digital Infrastructure*. Second, the Industry 4.0 transformation will require leadership and a thorough governance of the transformation process to secure a consistent implementation instead of disconnected initiatives in organizational silos. Third, the human factor: the

1 E.g. 'Leading Digital' (2014), 'The Digital Advantage – How digital leaders outperform their peers in every Industry' (2012), 'Digital Transformation – A Roadmap For Billion-Dollar Organizations' (2011)

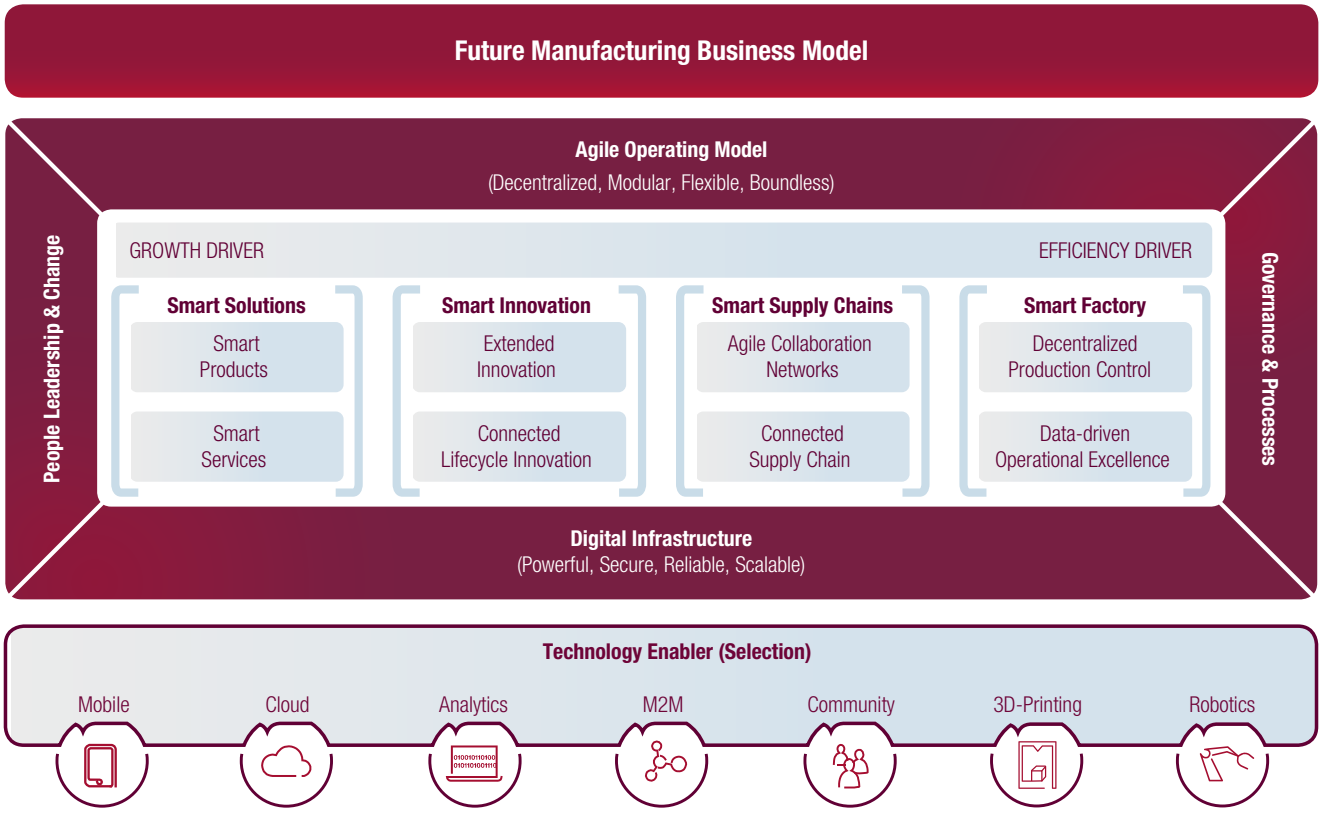
digital future will confront employees with radically new working modes and demand new capabilities. Finally, manufacturing operating models must overcome today's rigidity and respond to the business agility of the new industrial era.

Building an Industry 4.0 business model

The core value drivers of the fourth industrial era evoke disruptive changes in today's manufacturing business models. Traditional ones focusing exclusively on the product face extinction. New competitors arise and historical industry boundaries increasingly vanish. The industry leaders of the future will build a business model that combines a set of distinctively selected Industry 4.0 capabilities and value drivers, and embed them in corporate structures that are transformed accordingly.

An early sign of this development can already be witnessed: a vast number of start-ups are entering the manufacturing environment around the globe with very specific Industry 4.0 solutions. Overall, we will see a rise in multifaceted business models to conquer new grounds in an Industry 4.0 era notwithstanding the overall effect of classical industry borders becoming less and less rigid in the dawn of an 'Economy 4.0'.

The Capgemini Consulting Industry 4.0 Framework



Source: Capgemini Consulting

The Value Drivers of a New Industrial Paradigm

> Smart Products will enable completely new value propositions and business models

Industry 4.0 is often hailed as the key to a thriving manufacturing sector in the future. In order to better grasp what really stands behind this vision in terms of levers for business success, we have identified eight value drivers along four main pillars. *Smart Solutions, Smart Innovation, Smart Supply Chains* and the *Smart Factory* are the fields in which manufacturers can realize enormous potentials by digitizing their business. While Smart Solutions and Innovation primarily leverage company growth, Smart Supply Chains and Factories mainly drive efficiency.

Smart Solutions

Smart Products are cyber-physical systems[2] (in the following: 'CPS') providing new features and functions based on connectivity. *Smart Services* open up paths for entirely new business models and markets through innovative service offerings and delivery models.

Smart Products: a key to the future Industry 4.0 scenario

Smart Products incorporate self-management as well as communication capabilities, and trigger radically new business models in an era of decentralized decision-making and autonomous operations. Smart Products are CPS equipped with sensors providing information about their environment and, for example, their current use and status. The data is linked to an actuator able of triggering autonomous reactions to changes. Connectivity provides *Smart Products* with the ability for machine-to-machine communication, and embedded interfaces enable interaction with human users. This also forms the basis for cyber-physical production systems[3] (in the following: 'CPPS') and ultimately the *Smart Factory*.

Additional advantages of Smart Products include their adaptive features and opportunities for customization to better match their surrounding environment and tasks. Imagine a connected gas turbine interacting with social and machine networks to decide autonomously about service needs. Through its self-management, the turbine becomes almost invisible to its operator and requires attention only when triggering support or maintenance. In the long run, Smart Products will also be able to self-maintain configuration and functionality throughout their lifecycle and remain connected with manufacturers, providing them with a wealth of information for product optimization and innovation.

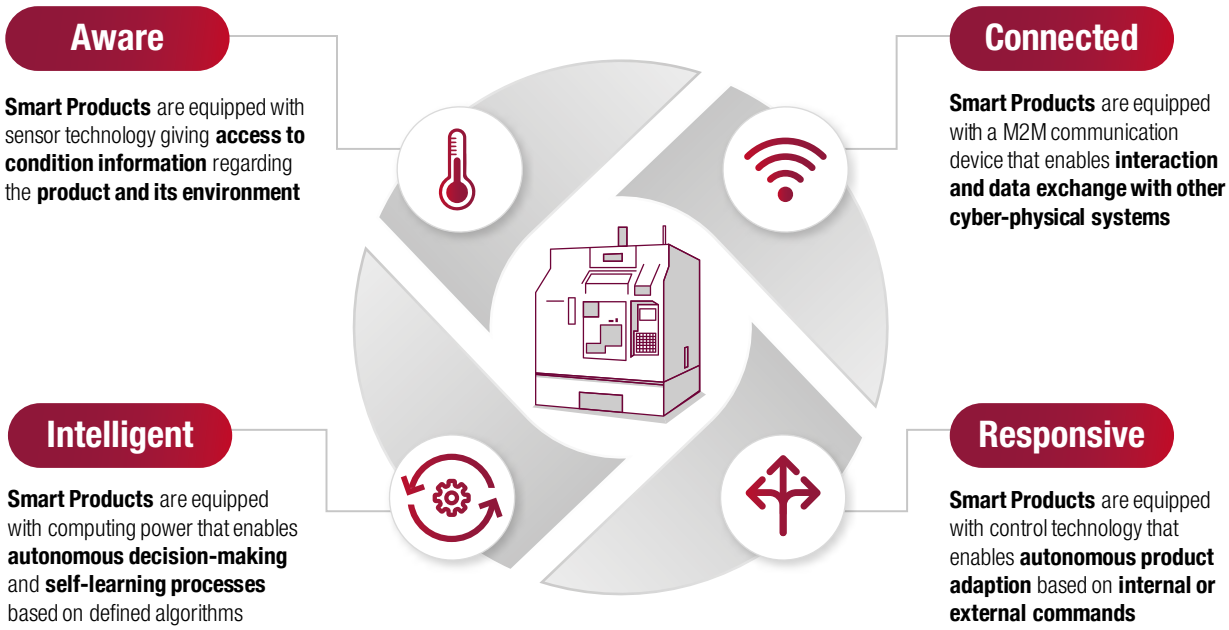
By enhancing mining diggers with infrared sensor technology, their movements when loading mining trucks can be adapted for an automatically optimized, collision-free path choice. Also, the digger can autonomously recognize the truck model it is loading and its current load factor, informing the operator about the optimal amount of material to load. In trials, process efficiency increases of 12% could be realized with this *Smart Product*.

Source: Siemens

2 A cyber-physical system is a physical object with an embedded system containing computing power (a CPU), data storage and a form of network connectivity.

3 Cyber-physical production systems are production systems consisting of one or more CPS.

Figure 1 - Defining characteristics of Smart Products



Source: Capgemini Consulting

Business impact: a huge potential for growth

Smart Products will drive revenue growth by enhancing the user experience and improving the total cost of ownership, which significantly intensifies the customer relationship and interaction: they will enable completely new value propositions and business models.

Constant communication and data analysis concerning the product's state builds the basis for expanding the (aftersales) service business. Predictive maintenance services, actively offered and tailored to customer needs, are the best example for this. In addition, based on the feedback and knowledge transfer abilities of *Smart Products*, new business opportunities through customization emerge, such as individual device software.

Smart Services: new service offerings and digitally enabled service delivery

The connectivity and rich data basis of Industry 4.0 together with powerful yet ergonomic analytics tools provide the foundation for new service offerings. *Smart Services* open up exciting paths to business growth. Moreover, digital technologies create further potential for optimizing existing service operating models.

Smart Services are enabled by the collection and processing of very large amounts of data. What is new is the fact that more and more ergonomic tools for a targeted use of this data exist. Analytic models support automated, intelligent decision-making as well as next-best-action suggestions. For instance, manufacturers or third-party service operators can make reliable predictions at which point in the future a production system will require maintenance, based on real-time data about the wear and tear of the system (predictive maintenance). The service process can also be automatically tailored to a customer's needs in real-time. *Smart Services* enabled by Industry 4.0 will also include pay-per-use service operating models, for example the provision of machines to the customer at no or low initial cost with the subsequent billing for their actual use. Furthermore, remote services of significant value-add will be possible in a networked industrial environment. For example, a production system's resource consumption could be optimized from a control room, and a *Smart Product* could be fully managed remotely. In summary, Smart Services include various types of offers with inherent intelligence by using digital technologies for the service's provision.

A fascinating example for a *Smart Service* is given by a large manufacturer of lighting solutions. The company is currently testing a service offer for local authorities to regulate inner-city traffic flows by dynamically increasing or decreasing street lighting intensity, enabled by smart lighting products. Among many other data, the street lights are able to measure traffic intensity as well as weather conditions and connect to a service cloud. By finding innovative ways of exploiting this data source, the manufacturer opens up entirely new streams of revenue such as this offer to public administrations.

Source: Capgemini Consulting client

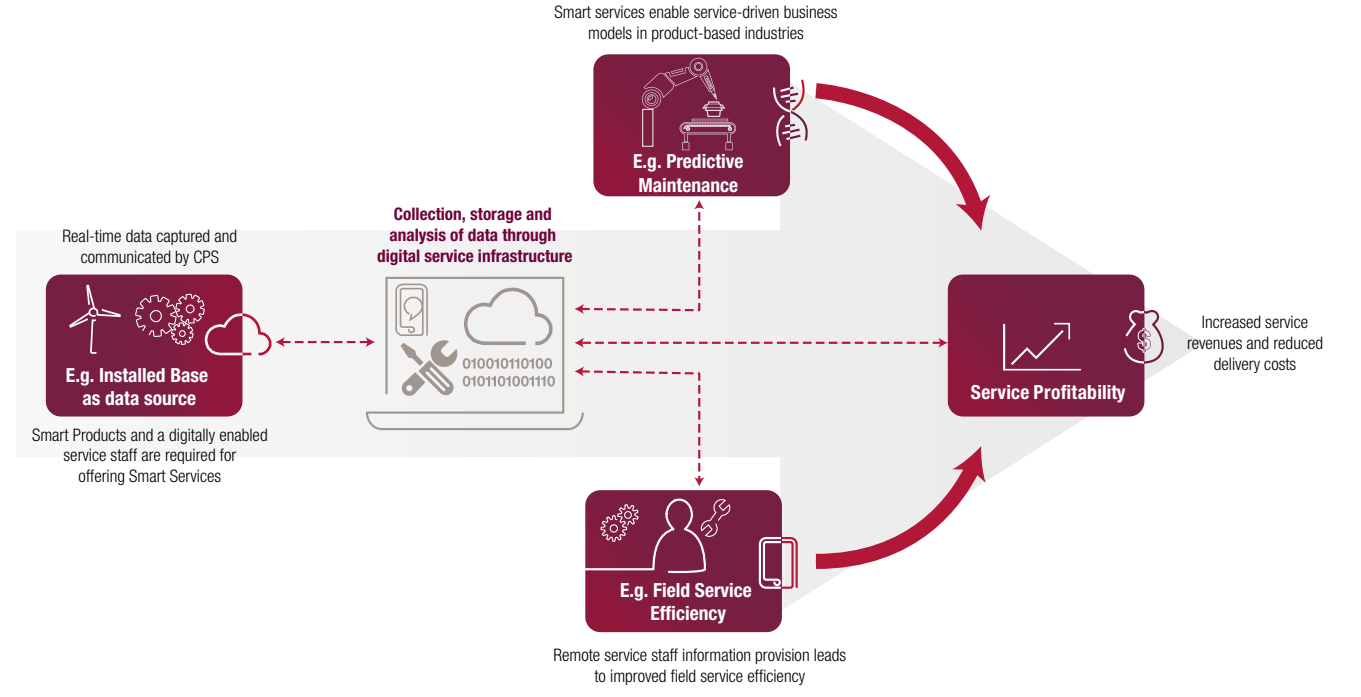
Business impact: new offerings, new markets

Smart Services will be a key market-side differentiator in the competitive environment of the future. Especially manufacturing companies based in high-cost countries need to leverage this opportunity in order to sustain their competitive edge and drive growth. *Smart Services* allow higher added value, enhance customer experience and intensify the customer relationship. The efficiency of service delivery can be greatly improved; the lifecycle value for associated *Smart Products* can be optimized. They represent an enormous potential to penetrate new service markets and build data-driven business models.

> Smart Services will be the most important market-side differentiators in Industry 4.0

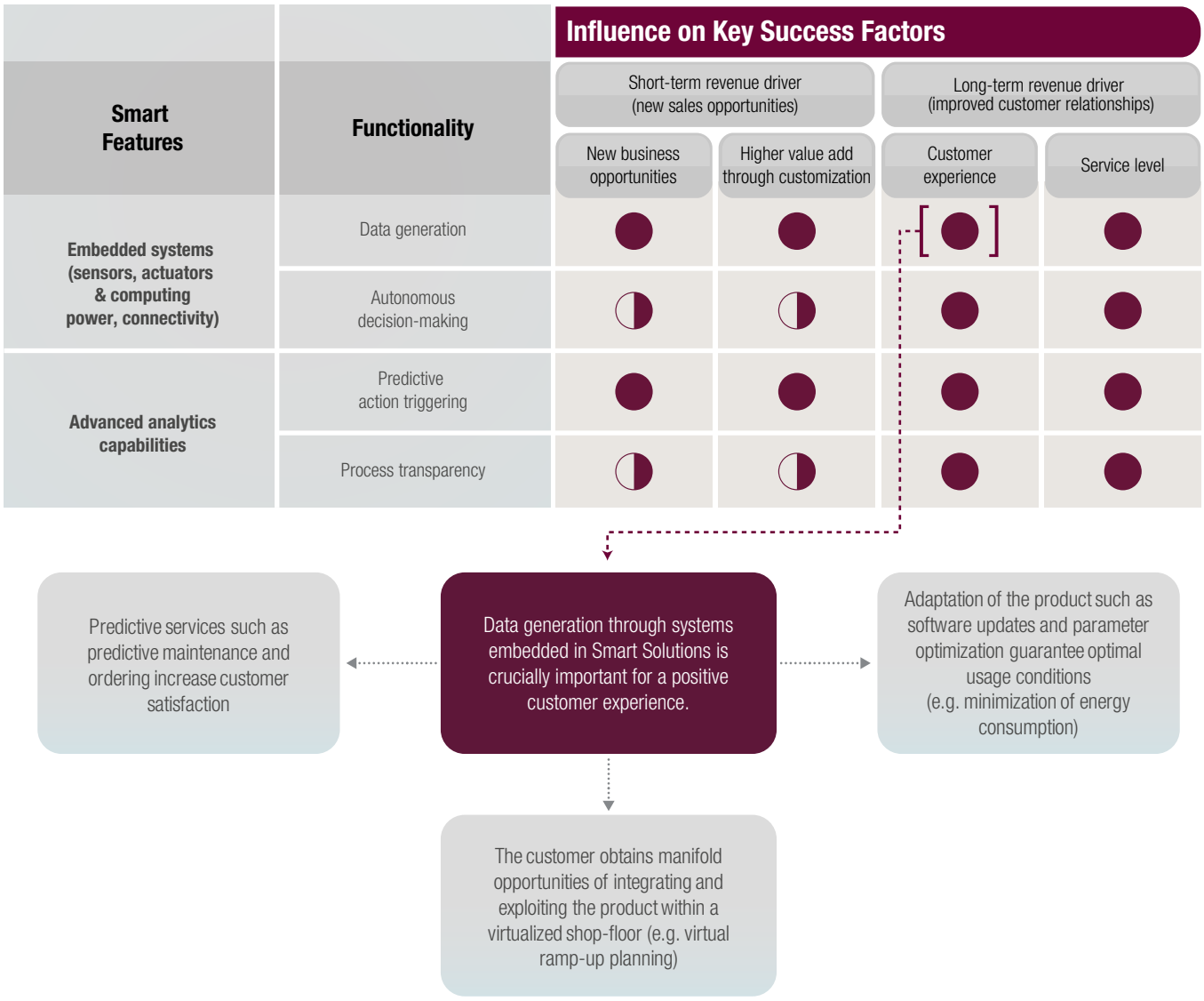
Overall, manufacturers will need to leverage innovative combinations of *Smart Services* and *Smart Products* to increase the scope of their value creation activities. This also represents one of the biggest growth potentials of Industry 4.0, as digital technologies substantially reduce the barriers for an up- or downstream expansion of the value chain. For instance, Vaillant, a manufacturer of heating systems, already acts as the operator of its products directly at the clients' sites through a *Smart Service*. A manufacturer of very large production equipment for the tobacco industry links its systems through predictive maintenance to an automatic replenishment service, ensuring clients' use of originals instead of third-party substitutes for the necessary wear and tear replacement parts. To put it in a nutshell, companies must aggressively leverage opportunities like these before their competitors do – or else they will be forced out of the market.

Figure 2 - Value creation through Smart Services and remote service delivery



Source: Capgemini Consulting

Figure 3 - Business impact: Smart Solutions



Relative impact: functionality has little impact on KSF ○–◑–● functionality is crucial for KSF

Source: Capgemini Consulting

Smart Innovation

Our vision of *Extended Innovation* embraces the creation and distribution of ideas across organizational borders, whereas *Connected Lifecycle Innovation* leverages product lifecycle data as a source for innovation.

Extended Innovation: creating innovation hubs

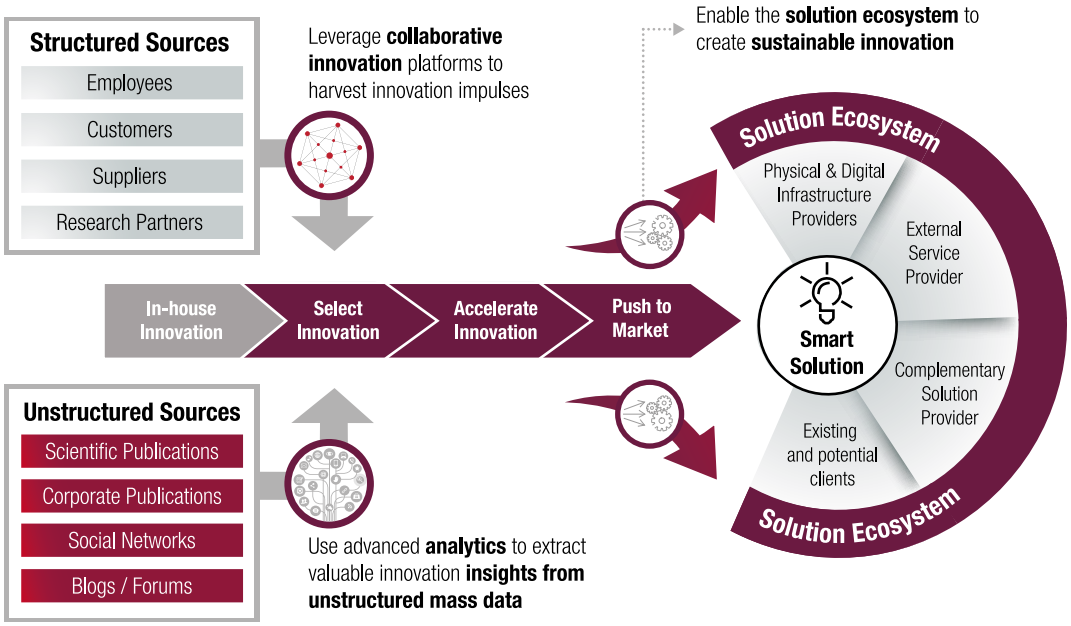
Communication and connectivity allow for cross-company innovation activities. Extended Innovation is a two-way exchange, with information flowing into and out of the company. While outside stimuli are actively brought into the company, it acts as a hub for then feeding them into the partner network to broadly support innovation and idea generation. Extended Innovation thus requires opening up innovation processes in manufacturing companies to external partners and customers. In a way, this has been established in the IT industry with open-source platforms long ago. More recently, Elon Musk aimed to spur innovation in the ecosystem relevant to Tesla, his company manufacturing electric cars, by publicly renouncing to pursue any company making use of their patented technologies "in good faith"[4].

New impulses can come from a multitude of sources outside the own organization, and they have to be proactively integrated into an open innovation process. However, in an interconnected Industry 4.0, ideas are much more valuable if they are embedded in an equally innovative periphery of devices or related solutions. The original owner of the innovation thus has to empower partners to participate in the process. By passing on knowledge and receiving the necessary support by the periphery, innovation will spread and will be more sustainable for all participants.

These 'outside-in' and 'inside-out' processes are enabled by digital technologies[5], such as community platforms platforms or collaborative PLM tools, connecting knowledge resources. Collaborative engineering activities, for example with the customer, are also greatly facilitated by the use of appropriate digital platforms and the availability of sophisticated virtual product models.

> In order to realize the vision of a 'connected car', vehicle manufacturers have to rely on customer-driven innovation (e.g. through social media or lead-users). At the same time, they will need their partner companies, like telecoms and tier-1 multimedia systems suppliers, to buy into and sustain the innovation process. Car manufacturers need to realize this through digitally enabled *Extended Innovation* processes.

Figure 4 - The building blocks and process steps of Extended Innovation



Source: Capgemini Consulting

4 Elon Musk: "All our patents belong to you", Tesla Motors Blog, June 12th, 2014.

5 More about digital technologies as the enablers of Industry 4.0 can be found in the chapter "The Digital Basis of Industry 4.0 – Technology Enablers" from page 20

Business impact: sustained innovation and competitive advantage

Extended Innovation will increase the customer-orientation of manufacturers' innovation activities. The overall frequency of impulses will be boosted by the exchange of information, creating competitive advantages for the leaders. Collaboration in the innovation process with both customers and partners will reduce the time-to-market and drive innovation speed towards a constant flow. Finally, innovations will become more sustainable by sharing information throughout the manufacturer's ecosystem.

Connected Lifecycle Innovation: tapping into a wealth of insights

While the great blue of ideas out there certainly has groundbreaking potential for innovation, the data gathered along product lifecycles provides a shockingly underexploited resource for innovation.

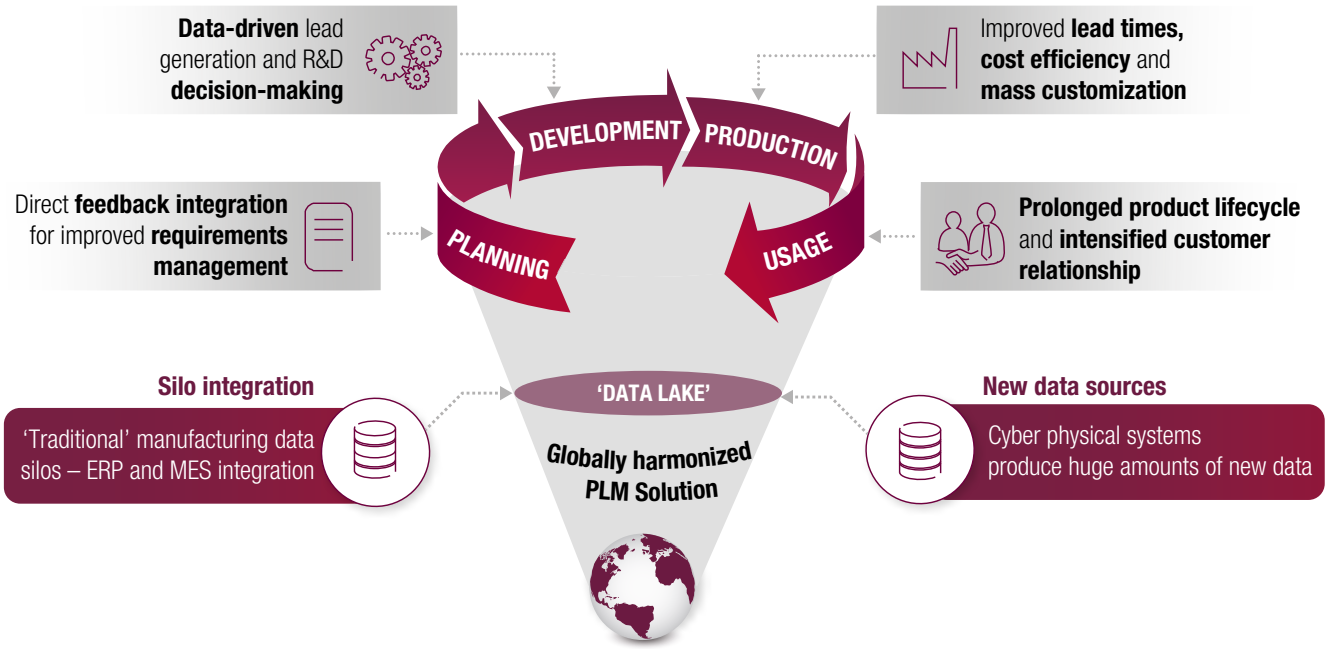
Combined with the analytical powers of digital tools, these increasingly rich datasets provide a chance to innovate with great benefits.

Connected Lifecycle Innovation differs from 'ordinary' product lifecycle management in its holistic approach: product-related information is coupled with other relevant data, such as machine parameters or customer order data. It is then analyzed, processed and put to use for generating innovation, enabling data-driven R&D decision-making and business process innovation throughout the entire organization, such as in sales processes. For instance, material choice can be optimized by systematically analyzing data from production processes. Even in more complex B2B markets, a customer's purchasing behavior can be predicted through analytical models, enabling much more efficient and successful sales activities.

Advanced PLM systems form the foundation for *Connected Lifecycle Innovation*. They should be accessible anywhere on the globe, especially through mobile applications. The interfacing with other relevant business applications as large hosts of data is a second major characteristic. Data from ERP systems and production-related applications such as manufacturing execution systems (MES) need to be accessible. This silo-free 'data lake' merges many more sources than classic PLM-related data. Furthermore, direct feedback should be supported through touch points with the customer. Finally, *Connected Lifecycle Innovation* is enabled by visualizing, aggregating and holistically analyzing this information.

> The data gathered along product lifecycles is a shockingly underexploited resource for innovation

Figure 5 - Technological basis and business impacts of Connected Lifecycle Innovation



Source: Capgemini Consulting

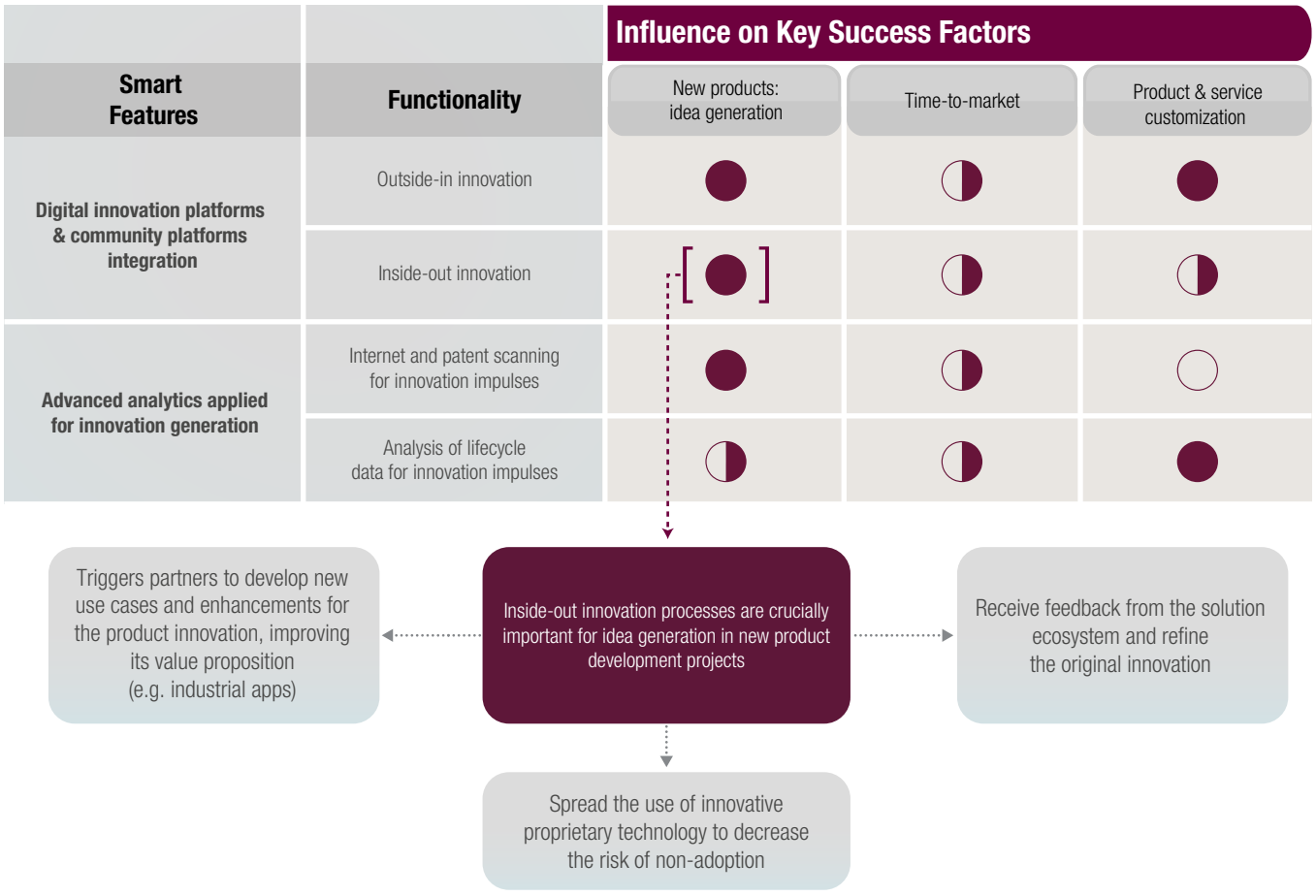
A global automotive company developed a mobile service solution based on a smartphone application for car owners. It allows them to scan the interior and engine compartment with the camera of their own mobile devices and automatically detects relevant vehicle controls, for example control lamps, displays or oil level indication. For the recognized elements, corresponding overlays on the camera view will appear. Besides being able to offer optimized service solutions to the users, the car manufacturer obtains direct, real-time data on product issues or failures and repair needs. This information is then used to improve product quality and service offerings.

Source: Capgemini Consulting client

Business impact: data-driven innovation focusing on the customer

Like *Extended Innovation*, *Connected Lifecycle Innovation* will lead to an increase of innovation frequency. It will reduce the time-to-market, implying growth potential as well as improved efficiency in operations, with decreased R&D cost. Client-specific data further provides the opportunity for more unique products and services through individualized innovation in the B2B sector. Additionally, product lifecycles can be prolonged and the lifecycle value optimized, generating additional sales propositions and a higher customer satisfaction.

Figure 6 - Business impact: Smart Innovation



Relative impact: functionality has little impact on KSF ○–◑–● functionality is crucial for KSF

Source: Capgemini Consulting

Smart Supply Chains

Smart Supply Chains are highly integrated and automated, enabled by the use of digital technologies and cyber-physical systems. Our vision of *Agile Collaboration Networks* describes the shift in horizontal integration towards a flexibly defined extended enterprise, enabling manufacturers to focus on core competences yet allowing them to offer customized products in any market. *Connected Supply Chains* are formed through the vertical supply network by recreating supply flows on a virtual level, allowing the seamless integration and automation of physical processes and providing companies with dramatically increased transparency.

Agile Collaboration Networks: benefitting from the globalized marketplace of competencies

In Industry 4.0, rigid collaboration structures will be increasingly replaced by project-based business partnerships. Such an ad-hoc setup of collaborations is needed to deliver solutions uniquely tailored to a customer's needs. Through Agile *Collaboration Networks*, manufacturing companies can truly leverage the opportunities arising from the globalized marketplace of skills and capacities.

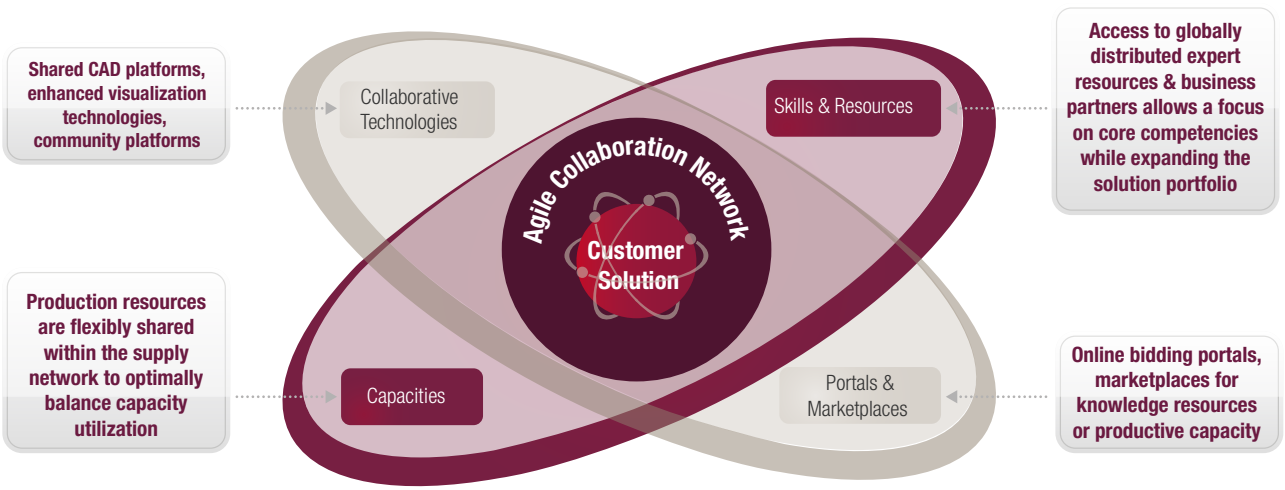
For example, a mid-size machine component manufacturer will be able to flexibly decide what should be done in-house or by a partner. It could work with engineering service providers globally through shared CAD platforms in order to develop specific system modules requested by the customer. Secondly, in its network of partner companies the manufacturer could allocate the production orders flexibly to the partner with the highest free capacities available, or acquire the necessary production capacity for the hardware through a broker intermediating between specialized production service providers and the manufacturer. The company itself might focus on the components' software, associated services, the delivery of the solution to the customer and the after sales activities. Business partnerships like these are enabled by digital technologies, which fuel collaboration by substantially decreasing its complexity.

A networked production environment and interconnected engineering platforms will form the basis for these networks. Furthermore, interfaces between companies in terms of organizational structures, processes and IT as well as standardized, portable data formats will be the key enablers for flexible collaborations in manufacturing.

A manufacturer of engines in the aerospace sector faced challenges with its external partners as the PLM tools in use were no longer sufficient in collaborating within the global extended enterprise. As a solution, a cloud-based collaboration platform was implemented. It enables the sharing of configurations and digital product models, while data segmentation ensures that security constraints are respected. Product data is synchronized in very short time intervals which means work is based on a 'single source of truth'. Through this digitally enabled *Agile Collaboration Network*, the company shortened the time-to-market for a new engine generation and reduced development costs by 20%.

Source: Capgemini Consulting client

Figure 7 - Technology layer and main elements of Agile Collaboration Networks



Source: Capgemini Consulting

> Through Agile Collaboration Networks, manufacturing companies can truly leverage the opportunities arising from the globalized marketplace of skills and capacities

Business impact: refocusing on core competencies while improving the value proposition

Agile Collaboration Networks will enable manufacturing companies to maximize their focus on core competencies even in strongly project-based businesses with highly individualized products. Leading companies will drastically improve the cost efficiency and flexibility of their operations while driving growth through improved, unique value propositions. Capacity bottlenecks can be overcome by assessing production capabilities together with collaboration partners. Product and service offerings can be expanded by leveraging external specialist resources and know-how.

Connected Supply Chains: continuously mapping physical flows

In contrast to *Agile Collaboration Networks*, which build on the horizontal integration of supply chains, vertical integration based on digital technologies allows companies to drive value through transparency and process automation. In such *Connected Supply Chains*, operating costs can be dramatically reduced.

The *Connected Supply Chain* will be a centerpiece of operational excellence in any Industry 4.0 strategy. In order to manage the growing complexity of supply chains, physical flows have to be mapped continuously on digital platforms. This virtual image of the supply network's activities is created through cyber-physical systems, such as RFID-tagged raw material and work pieces. Deployed along the supply chain, they generate data about goods' positions or states – in real-time, on multiple levels of aggregation. At the point of the data flows' aggregation, the supply chain control tower, a maximum level of transparency over the entire supply chain can thus be established.

This digitization enables the automation of routine supply chain processes such as delivery processing or warehousing operations. The human resources freed up can focus on resolving issues detected by analyzing the available data, creating enhanced economic value. Moreover, *Connected Supply Chains* allow the identification of the product all along the production process, enabling the manufacturer to be more responsive to change requests.

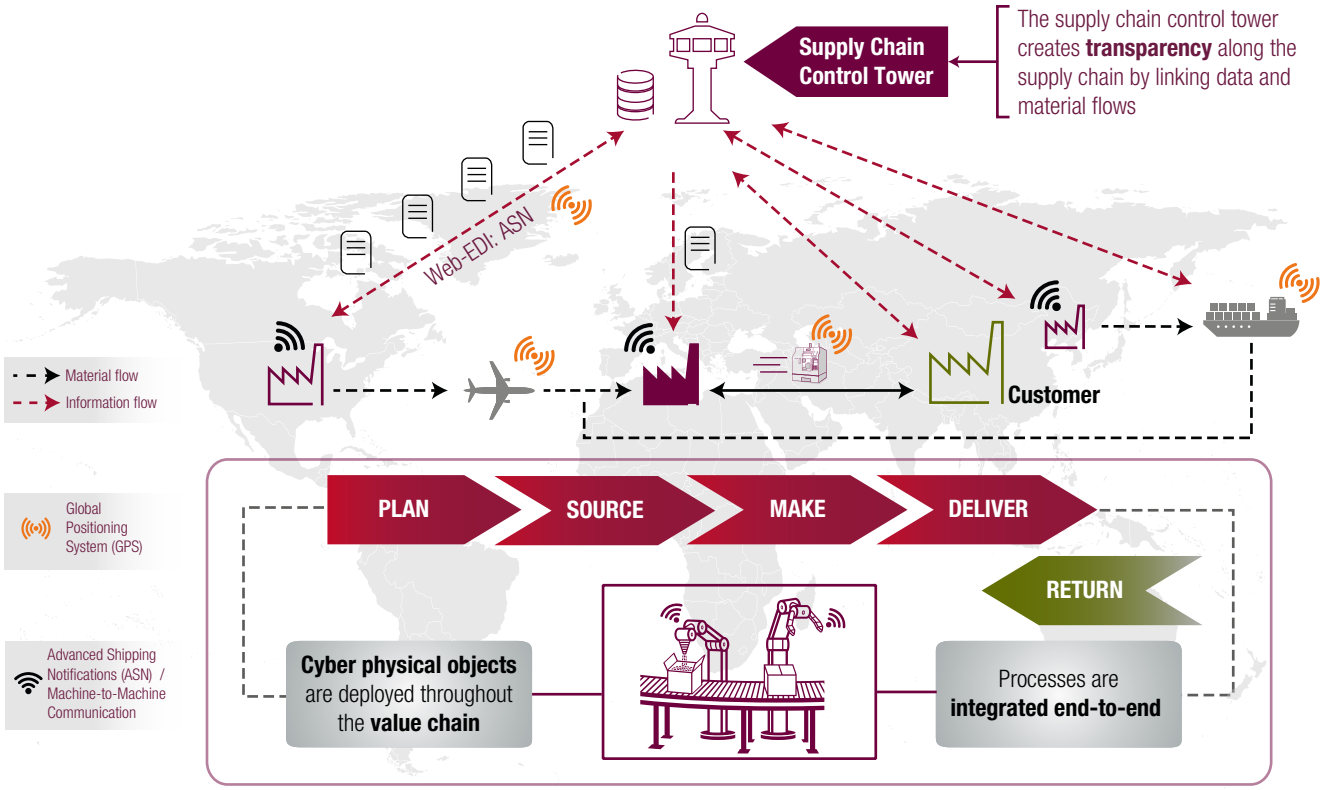
> Connected Supply Chains will be transparent, lean and cost efficient - they will form a centerpiece for operational excellence in any Industry 4.0 strategy

Pull processes and one-piece flow will be much more feasible in digitally enabled supply chains. Instead of supply issues, production systems' physical capabilities will represent the impediment to be addressed. Processes and organizational structures need to correspond to the end-to-end integrated vision of operations[6]. Hybrid elements, i.e. digital information alongside paper-based documents, need to disappear in order to realize the benefits of the *Connected Supply Chain*.

A worldwide logistics service provider offers real-time (excluding air traffic) solutions for shipments based on GSM and RFID technology to enhance supply chain transparency. Geo-location is tracked via GSM resolution and GPS, and freight data such as temperature, humidity or shocks can be monitored via sensors. An alert system informs in case of delivery irregularities. The solution allows companies to gain full visibility along the shipping process and react in real-time in case of delivery issues.

6 Cf. Capgemini Consulting (2014) Digitizing Manufacturing – Ready, Set, Go!

Figure 8 - Basic structure of a Connected Supply Chain



Source: Capgemini Consulting

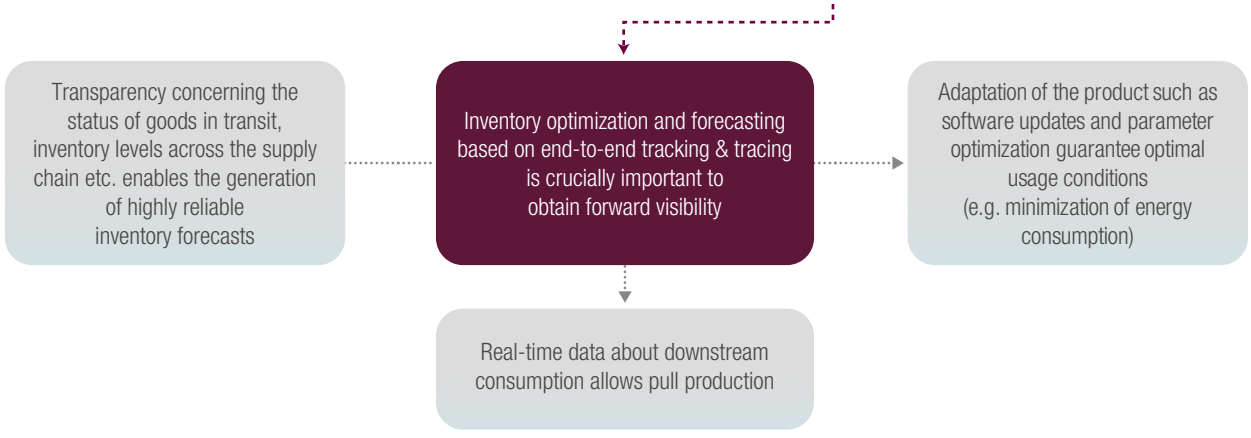
Business impact: visibility, reliability and agility of supply chain operations

Visibility of supply network movements is a first tangible impact of digitization. Inefficiencies and risks can be recognized and resolved at the source, instead of fighting only the symptoms of inefficient supply operations. This increases the robustness and responsiveness of the supply network to perturbations. The reach and precision of forecasts will increase and stock levels become highly predictable. The *Connected Supply Chain* will thus be a lean and reliable one. Overall, we estimate that transparency and process automation will lead to supply chain cost decreases of up to 20%[7]. *Connected Supply Chains* will also be agile, greatly facilitating the integration of changes in customer requirements.

7 Capgemini Consulting (2011) Digital Transformation of Supply Chains

Figure 9 - Business impact: Smart Supply Chains

Smart Features	Functionality	Influence on Key Success Factors				
		Supply chain efficiency			Growth through improved value proposition	
		Operating cost	Lead time	Forward visibility	Customer satisfaction	Enlarged solution portfolio
Online portals, marketplaces	Worldwide business partner selection	◑	●	○	◑	●
Interfaced manufacturing platforms	Cross-company CAx	◑	●	○	◑	●
3D printing	On-site production, elimination of transportation steps	●	●	◑	●	◑
End-to-end track & trace	Process automation	●	◑	●	◑	○
	Inventory optimization & forecasting	●	●	[●]	◑	○
Advanced analytics	Flow visualization & optimization	●	◑	●	◑	○



Relative impact: functionality has little impact on KSF ○–◑–● functionality is crucial for KSF

Source: Capgemini Consulting

Smart Factory

The *Smart Factory* constitutes the fourth pillar of our vision for Industry 4.0. CPPS[8] will be its basis. Through the networked array of machines, a new level of self-organization and process optimization is enabled in the form of *Decentralized Production Control*. Secondly, the exploding wealth of production-related information also provides the basis for *Data-driven Operational Excellence*.

Decentralized Production Control: transforming the production floor into a marketplace of capacity and production needs

The conquest of shop floors through CPPS and CPS will radically transform today's production planning and control. Instead of controlling the shop floor through a central MES[9], cyber-physical production systems will be able to make decisions locally, thus decentralizing production control.

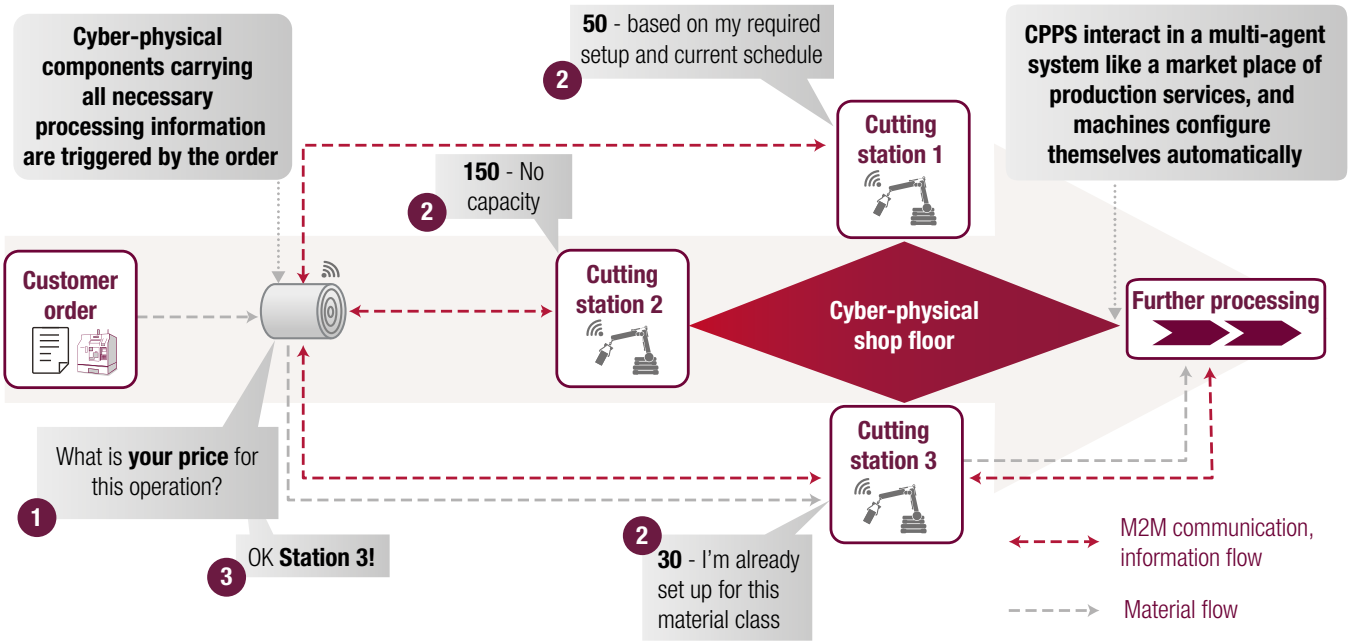
Through CPPS, the *Smart Factory* will be composed of intelligent production units knowing their current state and constraints, linked to the manufacturing ecosystem. As each production module will be able to obtain the information needed to make decisions autonomously, the shop floor will consist of a network of locally optimizing decision-making agents. Based on a multi-agent system, the production environment will organize itself. This could be realized through a market mechanism on shop floor level: the capacity of production systems represents the offer, while demand arises from the orders to be fulfilled. A price for machine processing times including setup costs can then be calculated, and together with other objectives, such as expected sales revenue or delivery dates, CPPS can individually decide on a profit-maximizing production schedule.

> Implementing decentralized control mechanisms will be the only way of managing the complexity of individualized industrial production

A *Smart Factory* pilot project in Germany illustrates the possibilities of Industry 4.0 with shampoo bottles. Each unfinished product is equipped with an RFID tag which transmits its target configuration to the production system, i.e. the need for either a white or a black cap to the bottling machine. The cyber-physical production system receives this information and can decide about the production needs. Without any further intervention of a centralized control instance, the process is hence self-controlled.

Source: Siemens

Figure 10 - The market mechanism enabling Decentralized Production Control



Source: Capgemini Consulting

8 Cyber Physical Production Systems, i.e. production systems digitally enhanced through embedded sensors, actuators, network connectivity and sufficient computing power as well as sophisticated software – see also p.6

9 Manufacturing Execution System

Business impact: mastering the complexity of individualized production

Given physically capable production processes, *Decentralized Production Control* provides the possibility of manufacturing each product individually without additional cost. Delivery dates will become highly reliable. Operational flexibility and productivity increase as the production line's finite capacities are allocated in the most efficient way. Contradicting targets and constraints are taken into account, and the overall production process can be holistically optimized. Taken to the next level, *Decentralized Production Control* may even provide a 'natural' way of optimizing the production network: market-like 'competition' ensures that only efficiently operating facilities will be selected from the resource pool when allocating production orders.

Data-driven Operational Excellence: exploiting the value of an underestimated resource

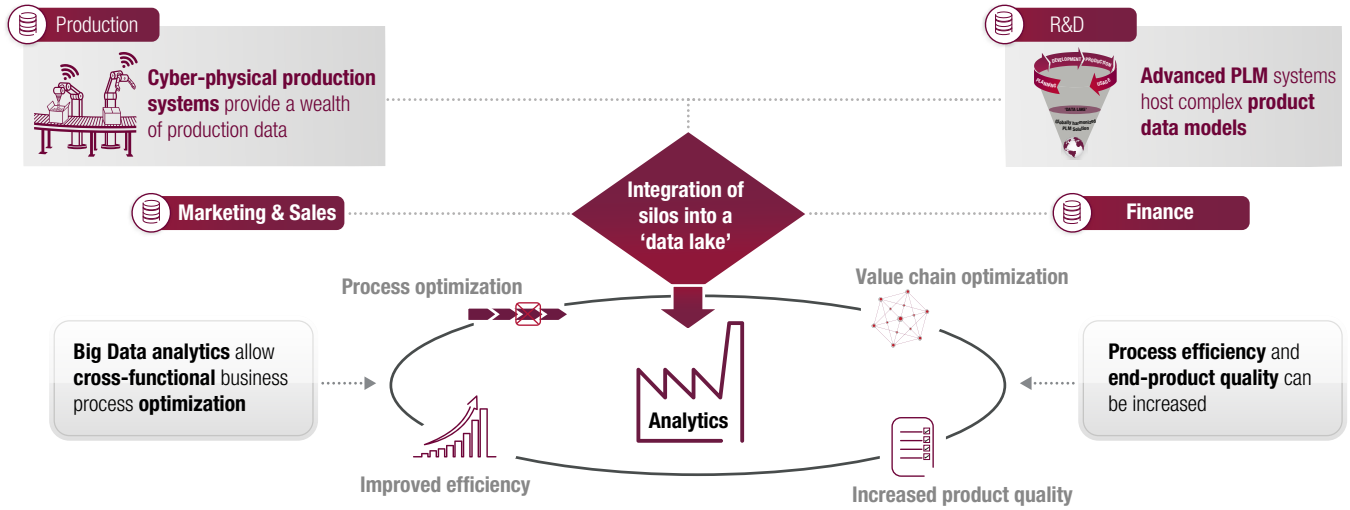
Data will be the great resource of the next industrial era. *Smart Factories* will produce huge amounts of it, and combined with the latest analytics technologies and expertise, *Data-driven Operational Excellence* will help to achieve yet unreachable levels of productivity and product quality.

The leaders in digitized manufacturing have already understood the value of data produced by CPPS and exploit it accordingly. By creating statistical process models and systematically analyzing outlier values, a light-alloy foundry operator, for example, was able to reduce its scrap rate by up to 90%.[10] Advanced analytics unlocks completely new insights on how to improve performance along the manufacturing value chain, detecting inefficiencies based on historical data and generating reliable hypotheses for optimization in the future.

Achieving the holistic view of operations throughout the *Smart Factory*, however, depends on the integration of relevant data from a multitude of different sources – siloed systems hinder the implementation of data-driven operations. Furthermore, technology allowing the real-time analysis of data, such as in-memory techniques, is important here. To put it in a nutshell, future manufacturing organizations will value and exploit data much more rigorously than ever before to reach new levels of operational excellence.

> A German tier-1 automotive supplier optimized quality assurance in piston serial production by realizing a 100%-control strategy. Through a data matrix code, each part is traceable through a data matrix code. A 3D x-ray control system installed in-line controls every part during the regular cycle time. This information is relayed in real-time to a database where it is compared to the original 3D model. Any production defects can thus be identified and defective products sorted out, realizing a defect rate of less than 1 ppm[11] in end products delivered to the customer.
>
> *Source: Automobil Produktion, Issue 5, 2013, p. 74.*

Figure 11 - Integration of data silos is the prerequisite for achieving Data-driven Operational Excellence



Source: Capgemini Consulting

10 Source: VDI Nachrichten, Issue 5, 2014, p. 12.

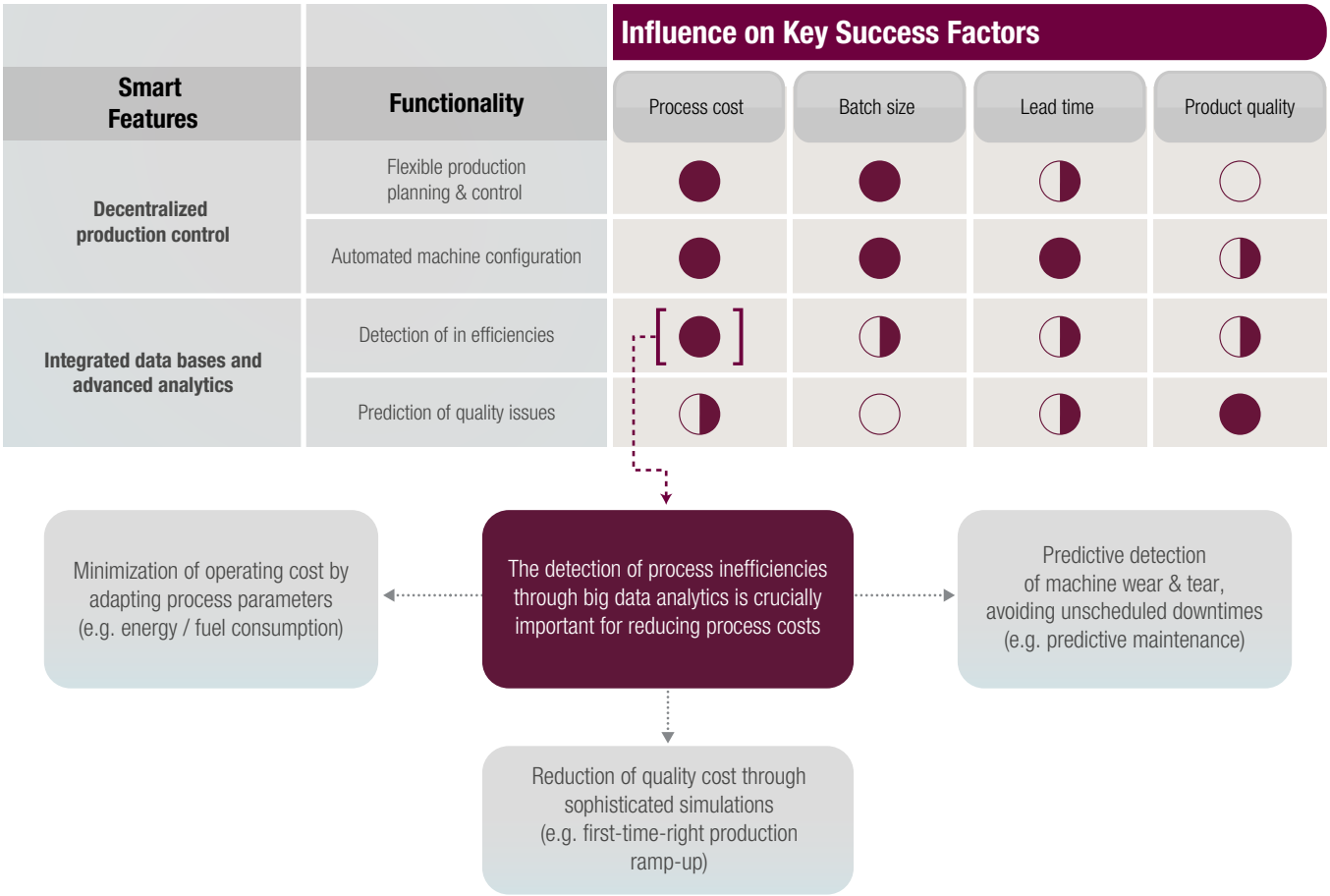
11 ppm = parts per million, i.e. less than 1 defect per 1 million units produced

> Data-driven Operational Excellence will help to achieve yet unreachable levels of productivity and product quality

Business impact: elevating operational excellence to new levels

The leverage of data in operations will provide competitive advantages by increasing process efficiency and end-product quality. Costs can be significantly reduced through more targeted quality assurance processes. Over time, internal benchmarks can be established and best practices derived from data. In addition, the reliability of productive assets and their long-term utilization are maximized.

Figure 12 - Business impact: Smart Factory



Relative impact: functionality has little impact on KSF ○–◑–● functionality is crucial for KSF

Source: Capgemini Consulting

The Digital Basis of Industry 4.0 – Technology Enablers

> Cloud technology is the key to a borderless flow of data as a vital aspect of Industry 4.0

The value drivers introduced above do not represent IT requirements but the business opportunities and needs created by a digitized industrial sector. However, it is the shift to digital technologies that so fundamentally affects the manufacturing sector and enables these value drivers. The concept of Industry 4.0 arises at a time as digital technologies coalesce into an ecosystem of 'Digital'. The successful transformation towards Industry 4.0 depends on the mastery of this ecosystem. Below, we introduce the seven key *Technology Enablers* defining it for the near future.

Mobile: delocalizing the value creation process

Mobile technologies include all wireless communication methods, be it via cellular connections or Wi-Fi and similar technologies. Enormous amounts of information previously available only at fixed locations are now accessible on-the-go. With regard to Industry 4.0, the mobile internet is vital for a connected production environment, for example regarding real-time data capturing and accessibility, object tagging and internet-to-object communication.

Cloud Computing: storage and computing power for digitally enhanced manufacturing

As a major prerequisite for value-added mobile services, Cloud Computing describes the applications, platform and infrastructure solutions delivered as services over public or private networks on a pay-per-use basis. CPS and CPPS[12] will produce huge amounts of data which need to be stored and processed. Analysis results need to be accessible anywhere around the globe, at anytime. Cloud technology enables this borderless flow of data as a vital aspect of Industry 4.0. It also eliminates the need for high-end user devices. Finally, capacity can be swiftly added, so much of the financial risk can be taken out of infrastructure investment decisions.

Advanced Analytics: transforming the data lake into a crystal ball

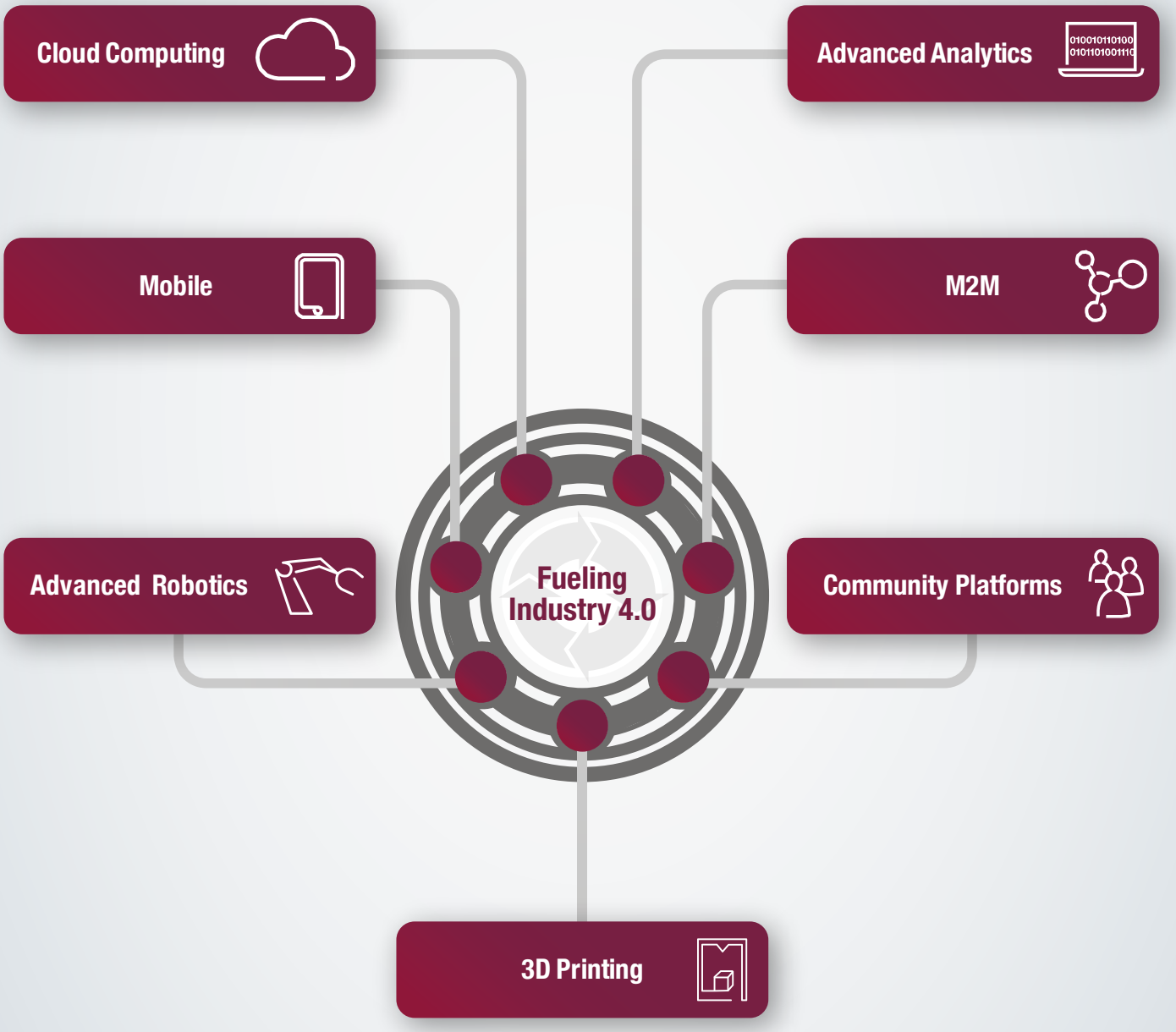
Advanced analytics aims for the generation of business insights from a pool of data by indentifying patterns and interdependencies. With increasing numbers of CPS in manufacturing and Smart Products on the market, the amount of data available to manufacturers will virtually explode. However, this valuable resource is yet often overlooked. Data analytics will enable manufacturers to analyze their operational processes and business performance, discover and explain inefficiencies and even predict future events. While often (falsely) associated with customer-focused processes only, analytics in manufacturing can help achieve outstanding improvements in operations as well!

Machine-to-Machine Communication: reducing complexity through coordination

Central to the shop-floor impacts of Industry 4.0, Machine-to-Machine Communication (M2M) refers to technologies allowing for the automated exchange of information between the CPS which constitute the Industry 4.0 production environment. M2M can be considered the integral technology of the 'Internet of Things' (IoT). Through advanced embedded sensor and actuator applications technology, the entire production floor can relay

12 CP(P)S: cyber-physical (production) systems; see also footnote on page 6

Technology Enablers



Source: Capgemini Consulting

> 3D printing is going to have game-changing impacts on how, where and by whom products will be manufactured in the future

meaningful information, forming the interface between the physical and the virtual worlds. This provides a level of transparency that enables huge improvements in manufacturing, from performance management to entire new business models. While the most evident usage forms of M2M will be in intra-company linking of production assets, M2M is also the key enabler when it comes to cross-company operations.

Community platforms: enabling new forms of coordination and collaboration

Community platforms have changed our daily lives through the instant, global communication of one-to-many. These portals are not limited to Facebook or Twitter. They encompass sophisticated, enterprise-grade offers which leverage employee collaboration to achieve a more dynamic, content-rich interaction with collaborators and customers. Many other enterprise applications now also incorporate community platforms elements. The human-to-human aspect of a networked industrial environment is substantially facilitated and enhanced through this technology. Furthermore, the 'classic' social networks can, for example, be applied for easier on-demand manufacturing and provide a wealth of data about customers.

3D printing: manufacturing anytime, anywhere

As with the cloud, manufacturers have long overlooked the real impact of 3D printing. Also called additive manufacturing, it refers to the production of three-dimensional objects directly from virtual models. Industrial use of the technology up to now has been scarce due to slow production rates, few available materials and high prices. As recent innovations alleviate these weaknesses, chances are that the use of additive manufacturing will mostly eliminate the efficiency disadvantages of producing individually customized products. This allows for rapid prototyping and highly decentralized production processes: the product model could simply be sent off to the 'printing' site nearest to the customer, eliminating intermediate manufacturing steps, transportation and warehousing. 3D printing is going to have game-changing impacts on how, where and by whom products will be manufactured in the future.

Advanced robotics: digitally enhanced contributors to human productivity

Technological innovations have substantially augmented robotics over the past decades, making robots employable in almost every sector. Especially sensors and machine vision coupled with improved artificial intelligence allow advanced robots to fulfill their role in manufacturing as independent productive units safely alongside shop-floor employees. In Industry 4.0, they will be decisive for process efficiency and reducing complexity.

> Manufacturing companies need to translate their Industry 4.0 business objectives into a technology roadmap outlining focus areas for future investments

Cloud Computing, Advanced Analytics and M2M should be the top priorities for manufacturers

Although each of the seven technology enablers introduced above is important for realizing Industry 4.0, some of them should be clearly on top of executives' priorities: those necessary for achieving the integrated data management and exploitation much of the potential of Industry 4.0 is based on. Cloud-based platforms[13] provide the universally accessible and powerful "single source of truth" necessary in a connected industrial environment. Successfully employing analytics capabilities is the key to exploiting this wealth of data for almost all of the value drivers of Industry 4.0. Machine-to-Machine Communication will be essential for connecting shop-floor operations to the virtual dimension of manufacturing. Finally, mobile technologies ensure the seamless participation of all necessary data sources and users. This bundle of technology enablers can be seen as the core set of Industry 4.0's technology enablers. The remaining three – community platforms, 3D Printing and Advanced Robotics – are still essential in particular settings and value drivers, of course, and must also be considered when designing a manufacturing organization's Digital Transformation. Figure 13 details this prioritization of technology enablers for the value drivers of Industry 4.0.

Figure 13 - Assessment of Technology Enablers' importance for realizing the value drivers of Industry 4.0

	Mobile	Cloud	M2M	Advanced Analytics	Community Platforms	3D printing	Advanced Robotics
Smart Products	●	●	●	●	○	○	○
Smart Services	●	●	●	●	○	◑	◑
Extended Innovation	○	●	○	●	●	○	○
Connected Lifecycle Innovation	●	●	●	●	◑	○	○
Agile Collaboration Networks	○	●	○	◑	●	●	●
Connected Supply Chain	●	●	●	●	○	○	○
Decentralized Production Control	◑	◑	●	●	○	●	●
Data-driven Operational Excellence	◑	●	●	●	○	○	○

Technology Enabler relevancy: Technology Enabler is of little importance for realizing this value driver ○–◑–● Technology Enabler is crucial for realizing this value driver

Source: Capgemini Consulting

13 While non-critical information can be stored on platforms in public clouds, private clouds accessible only within the own firm's organizational boundaries can be used for mission-critical data and applications

Requirements for Digitally Transforming the Manufacturing Organization

The value drivers outlined above arise from the orchestrated use of the respective Technology Enablers. However, a new industrial revolution cannot merely be about implementing new tools or systems. It requires manufacturing companies to profoundly transform their organizations. In the following we outline what we consider the major requirements for becoming Industry 4.0-ready.

Digital Infrastructure

Digital Infrastructure plays a crucial role: it incorporates the *Technology Enablers* into the firm's activities. In the hype around the concept, this underlying 'substrate' is often overlooked. While the technological possibilities in industry are evolving at a fast pace, both the quasi-public infrastructure (e.g. fiber-optic cables or the mobile networks operated by private companies) as well as intra-firm IT infrastructures are evolving much slower. Yet they are a critical component for Industry 4.0.

> Manufacturer's Digital Transformation must be based on a powerful, secure, reliable and scalable Digital Infrastructure

Certainly, much of the work ahead concerns parts of the *Digital Infrastructure* which are in the public sphere. Nevertheless, manufacturers have many levers for ensuring the adequacy of their *Digital Infrastructure*. We are convinced that manufacturing firms must achieve four requirements in order to allow the possibilities of Industry 4.0 to unfold their potential.

Making your Digital Infrastructure powerful

With the enormous growth of data traffic over the coming years[14], there is no doubt that particularly mobile networks need to be expanded in the future. Manufacturers should thus try to rely on the non-licensed mobile spectrum (e.g. Wi-Fi, Bluetooth) whenever possible. Furthermore, firm-specific infrastructure has to deliver the computing power necessary for complex processes. Intra- and extranets must have connectivity sufficiently powerful to accommodate peak data loads. When implementing new systems, only interfaceable infrastructures and systems designed according to SOA principles[15] can be powerful enough for Industry 4.0.

Making your Digital Infrastructure secure

In Industry 4.0, manufacturing companies will continue the virtualization of valuable business assets, such as new product designs. Both within companies as well as in the cross-company collaborative environment that firms rely upon, this valuable data must be secured against loss or theft.

Data segmentation and communication policies will be essential here, but the *Digital Infrastructure* also has to play its role by employing the latest data protection mechanisms. Staying up to date on the developments in enterprise security is the key recommendation here – and that IT security will not come for free, so investments in this area must be anticipated and planned.

Making your Digital Infrastructure reliable

As manufacturers will often rely on virtualized business processes, their *Digital Infrastructure* has to offer enterprise-grade availability rates (often stated with a target of 'three nines', i.e. 99.9% of availability[16]). For individual IT components, this could result in much higher availability requirements – think of 'single points of failure'.

Companies need to focus on the stability of the infrastructure employed. Stringent service level agreements must be made with cloud providers, for example. Minimize the number of single points of failure. Localize critical *Digital Infrastructure* in areas less prone to disasters or energy insecurity. If there is no standard in your industry or partner network for a particular technology yet, choose the ones with the most promising outlook of becoming the standard in the future.

Making your Digital Infrastructure scalable

The journey to Industry 4.0 will more often than not be an evolutionary one, functions and processes will be 'virtualized' at different times. In order to optimize the trade-off between system performance, i.e. the load and functional perimeter a system is capable of handling, and the associated costs, the infrastructure employed must be scalable. It has to enable the flexible adding of capacity and the incorporation of new functions or requirements as needed. Manufacturers should therefore consider the deployment of cloud services over on-premise solutions.

14 For 2015 the total internet traffic is projected to already amount to 1,000 EB, more than 30 times the amount of 2005 (Sources: World Economic Forum)

15 SOA: Service Oriented Architecture

16 This results in a maximum downtime of 8 hours and 46 minutes per year

Digital Infrastructure

Power

Virtualization

Data Segmentation

Internet of Things

Interfaces

Digital Infrastructure

Technology Enablers

Security

Standards

Hyperconnectivity

Scalability

Integrated Data Management

Public Network Infrastructure

Single Points Of Failure

Service-oriented Architectures

Service Level Agreements

Reliability

Source: Capgemini Consulting

Governance & Processes

Even if it is supported by an appropriate *Digital Infrastructure*, the transformation process towards Industry 4.0 can only be sustainable and successful if it is founded on coherent governance. Changes as profound as those ahead need to be managed through dedicated structures.

The transformation process should be driven by top-down governance

In our joint research program with the MIT Center for Digital Business[17], we have shown that the success of Digital Transformation is highly dependent on clear top-down governance. An uncoordinated array of bottom-up initiatives will block the path towards Industry 4.0. Organizational silos must be aligned to a common target setting. Especially the separation of business and IT functions we often witness today will prove to be a true show stopper. The governance mechanisms for steering the transformation need to ensure that business and IT mutually push for the initiation and sustained drive of technology-based change. IT must come to be seen as a central business enabler. For this, clear roles and responsibilities in the organization's digital initiatives have to be defined. Our previous research has shown that dedicated committees, shared corporate-level units and new roles, especially 'digital czars', are key mechanisms in this respect. For instance, many companies have created the position of a Chief Digital Officer who coordinates the company's different digital initiatives in order to maximize synergies.

> IT must come to be seen as a central business enabler

Operationally, the transformation program must be based on sound program management processes. High-level executives should be included in the management of the initiatives in order to ensure that the leadership's vision translates into daily business. There should be room for iterations and improvement of original plans: a transformation as profound as the digitization of manufacturing cannot be exhaustively planned in advance, and new ideas must be taken aboard along the way.

People Leadership & Change

'Change' will become ubiquitous in an Industry 4.0 manufacturing sector, rising in frequency and intensity[18]. In parallel, management's hierarchical powers will change through decentralized structures and virtual forms of collaboration, as core teams shrink and external resources are increasingly involved. Managing these changes will be important for the transformation process. New challenges also arise for company leaders in the long run. Make no mistake: the people dimension of 'digital' is at least as challenging as the technical one.

Managing the change starts with an emotional case for transformation

Many manufacturing companies still fail to systematically manage change related to Digital Transformations. We have found that a compelling, comprehensive vision for their 'digital future' is often missing among manufacturing companies.[19] Such a vision is the starting point to Industry 4.0. It should illustrate how the future organization will look like in a tangible and inspiring way. This 'digital vision' is going to form the basis for the emotional access company leaders will increasingly need to their organization.

To master transformative changes, adequate resources should be allocated to accompany the organization. Managers should allow time for sustainable results instead of focusing too much on 'quick wins'[20]. Attention must be paid to the number and sequence of particular change initiatives, so that the leaders of the change are not overburdened. Pilot projects should be conducted early on to provide a basis for learning. Middle and lower management require particular care during the change process, as they will be the leaders closest to the employees and often the first point of contact. Resources need to be devoted to enable these managers to act as transformational leaders.

17 MIT Center for Digital Business and Capgemini Consulting (2012) The Digital Advantage – How Digital Leaders Outperform Their Peers in Every Industry

18 Capgemini Consulting Change Management Study 2012: Digitale Revolution – Ist Change Management mutig genug für die Zukunft? (available in German only)

19 Capgemini Consulting (2014): Digitizing Manufacturing – Ready, Set, Go!

20 Capgemini Consulting Change Management Study 2012

Industry 4.0 requires the creation of a learning organization

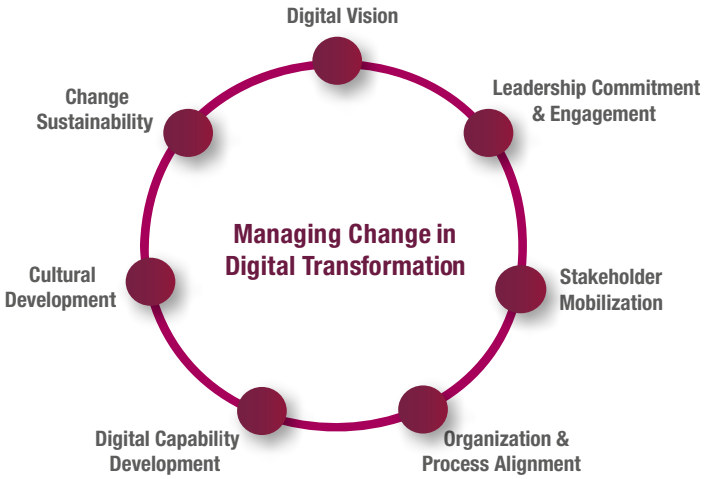
A major component of successful leadership in Industry 4.0 will be the ability to create a learning organization: the value over time of fact-based knowledge is becoming smaller and smaller in a sector driven by digital innovation. In this context, the attitude and capability to continuously learn will be vital. Company culture should be open and ready to share knowledge instead of using it as a tool for power – how else could companies benefit from value drivers such as *Extended Innovation?*

> A compelling, comprehensive vision for the digital future is the crucial starting point for Industry 4.0

Digitized manufacturing processes will also bring about big challenges for many manufacturers in terms of employee skills. New capabilities will be needed in many functions, not only in IT-related domains. R&D departments more than ever have to develop a systems engineering approach and skill set, i.e. thinking in product functions instead of technical features. Software will become an integral part of manufactured products, so manufacturers have to establish the corresponding skills. As a final example, today's machine operators will have to become analysts of production-related data, able to derive meaningful insights into process quality from a bulk of information.

Company leaders thus have to focus on identifying additional skill sets needed for their particular vision of a future, digitized manufacturing business. Next, they have to develop existing or hire new employees to fulfill these requirements. In terms of people development, the focus should lie on enabling learning all along the career path, with flexible working models and blended learning methods. The fostering of a 'digital mindset' is a crucial aspect. If not tackled early on, a lack of required skill profiles may eventually prove to be a bottleneck on the way to Industry 4.0.

Figure 14: The seven dimensions of managing change in Digital Transformation



Source: Capgemini Consulting

The Agile Operating Model

'Agility' in manufacturing can be defined as a company's ability to thrive in a competitive environment of continuous and unanticipated change. The transition towards Industry 4.0 will be a process of disruptive change, and a very dynamic future manufacturing environment can be expected. We are convinced that the ability to react to changes in the short term should be a vital attribute to consider when thinking about the design and control of manufacturing activities in Industry 4.0. Changes on short notice in customers' needs or the competitive environment, driven by technology, will increasingly occur in Industry 4.0, and agile manufacturers will reap competitive advantages in this environment.

Manufacturers' operating model should be decentralized

Manufacturing companies have long been dealing with the trade-off between centralized and decentralized operations. In the Industry 4.0 scenario, the most important argument for centralization, economies of scale, will be drastically weakened. Some of the well-known mechanisms behind economies of scale are increasingly invalidated by digital technologies. For example, think of the evolving technology of 3D printing within the context of learning curves: given a constant programming code, a 3D printer will produce the first piece as efficiently as the 1,000th.

Going forward, manufacturing companies need to target opportunities to decentralize building blocks of their operating model, thereby increasing their ability to respond quickly and effectively to local market developments. The localization of solution portfolios and sourcing markets, i.e. their adaptation to local market characteristics, is one aspect of this. Another is to develop the mechanisms for balancing globally decentralized resource networks in order to achieve efficient utilization.

Manufacturers' operating models should be modular

The manufacturing environment is becoming progressively more dynamic on the way to Industry 4.0. New market players, technologies and product opportunities emerge rapidly, others disappear equally fast. In order to remain sufficiently agile, manufacturing companies should aim to organize their businesses encapsulated around their core solution or processes. Business units should be induced to foster an entrepreneurial character. The integration or separation of a 'module' should be possible without strenuous periods of transition, for example through scalable steering mechanisms and information systems.

Manufacturers' operating models should be flexible

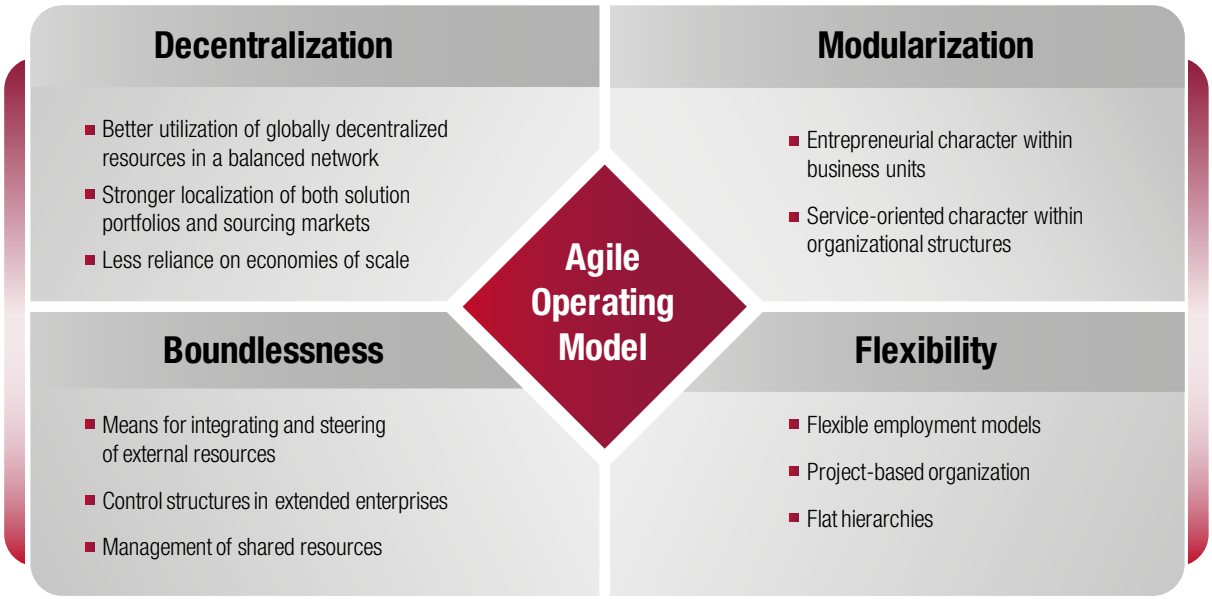
Manufacturing organizations remain agile if their structures are flexible enough to 'breathe' quickly when adapting to challenges and opportunities. Rigid corporate structures must be replaced by an organizational design allowing elasticity in daily operations. Project-based teams should be considered whenever appropriate. Flexible employment models provide the leeway to react quickly to changes. Outsourcing reduces the burden of high fixed costs. Most importantly, flat hierarchies and increased decision-making powers on lower levels enable firms to act with agility.

Manufacturers' operating models should be boundless

Today's manufacturing operating models often imply organizational barriers impeding the boundless value creation Industry 4.0 builds on. In organizations characterized by dwindling hierarchical control, manufacturers have to find solutions to seamlessly integrate and steer external resources. Approaches for controlling operations despite disappearing boundaries have to be developed. Questions of information ownership are also important in this context. The virtual product model, for instance, must be a boundless resource, but it is also a valuable one. Issues such as the operation and financing of shared systems arise. In order to allow the extended enterprise to flourish, manufacturers must proactively work at creating an organization befitting changing realities.

The implications Industry 4.0 holds for the manufacturing operating model are enormous; their reach cannot yet be entirely grasped. Above we have identified four characteristics we believe are especially significant for getting ready to reap the benefits of Industry 4.0's value drivers. However, yet of greater importance is the fact that companies indeed have to start envisioning how to shape their operating model in the future. There is no one-size-fits-all solution, and manufacturers should start looking for theirs sooner rather than later.

Figure 15 - Essential characteristics of an Agile Operating Model for Industry 4.0



Source: Capgemini Consulting

The Future Manufacturing Business Model

The past decades have already shown that the advances in information technology and globalization, among other factors, have significantly impacted even the largest firms: while in 1982 the Dow Jones Industrial Average was composed to 80% of the same companies as almost three decades before (in 1956), this ratio had plummeted to only 33% by 2011[20]. Compared to this development, we believe that Industry 4.0 will mean yet a lot more volatility for the manufacturing industry. A significant share of even its largest companies will not exist anymore in 2030.

Facing the disruptive changes ahead, manufacturing companies are challenged with one core question: how can I adapt or even revolutionize my business model in order to optimize the generated value in the next industrial era? We believe that focusing on a portfolio of digitally enhanced solutions will be one pillar of success. The other will be a decisive strategy which makes the best of Industry 4.0's value drivers and organizational requirements, optimizing the value creation in your particular setting. This will all happen in the light of fundamental changes to the sector's competitive structures. We expect digital giants to push into manufacturing. From the bottom, start-ups with 'Industry 4.0' programmed into their DNA will conquer niches and nibble away at manufacturers' market shares. Established manufacturers themselves will enlarge the scope of their value creation, thus also contributing to mounting competitive pressures.

Expert solutions delivered in a digitally enhanced environment

We are deeply convinced that Industry 4.0 will bring about solution portfolios better focused on the needs of individual customers than ever before. The *Future Manufacturing Business Model* will thus be based on strongly individualized value propositions. In addition, a single value proposition will consist of a comprehensive solution covering complementary products and especially services. The creation of a 'solution ecosystem' will also influence manufacturers' business models either through the development of the appropriate portfolio or in the search for the right partners. The optimization of the products' lifecycle value (e.g. an increasing service orientation) and open interfaces will move into the spotlight.

Strategically positioning the firm in Industry 4.0

Even more than the design of a digitally enhanced solution portfolio, the fourth industrial revolution will force manufacturers to rethink how to actually create this value, i.e. rethink the back-end of their business models. Company leaders should decide on which fundamental drivers to base their business in the future. Should it be…

- …an innovation-driven one, based on a strong partner network and Smart Innovation processes, whilst outsourcing major physical production processes?
- …an extremely agile production focusing on customized products in batch sizes of one, enabled by Smart Factories?
- …an efficiency-driven one, with low prices and market-beating lead times, made possible by a Smart Supply Chain?
- …a service-based one, transforming the manufactured product to serve only as the source for valuable data and the door-opener to a wealth of Smart Services around it which form the actual value proposition?

No matter the particularities, companies have to assess their vision of the industrial future and then decide how to move forward: pursuing existing strategies with reinforced vigor or developing new strategic approaches to successfully emerge from the fourth industrial revolution.

> Focusing on a portfolio of digitally enhanced solutions will be one pillar of success. The other will be a decisive strategy which makes the best of Industry 4.0's value drivers and organizational requirements

A large manufacturer of lighting solutions is currently piloting a concept to equip entire municipalities with its high-end street lighting solution – for free. The solution generates revenue not from selling the physical products but from the data they collect. The lamp posts and light bulbs are connected to a 'service cloud' and contain sensors measuring data such as energy consumption, environmental conditions and whether a pedestrian or car actually passes by or not. This data can be applied to manifold uses, from reducing energy consumption to optimizing road safety and insurance policies. The manufacturer has recognized the value of this data and is acting upon it – by transforming its business model from a traditional, product-based one to selling data and associated *Smart Services*.

Source: Capgemini Consulting client

20 Source: Capgemini Consulting analysis

Market Players in Industry 4.0

Source: Capgemini Consulting

> Start-ups will build business models that focus on very specific solutions among the Industry 4.0 value drivers

Market players in an Industry 4.0 scenario

Next to the pressure originating from established competitors, new players will push into the manufacturing market. Digital giants (e.g. Google, Amazon or IBM) expand their business activities to many different industries and small start-ups drive new business models fit for a digital economy.

Digital giants

The players we refer to as digital giants already leverage their digital competence to enter various industries. While manufacturing has not been significantly impacted by this development yet, we expect them to reach out for their market stake in the near future. Currently we can already observe that digital giants start to build and acquire manufacturing know-how. Elon Musk, for example, is riding the wave of digital competence and has established companies such as Tesla Motors and SpaceX. Google develops self-driving cars and is buying some of the world's most advanced robotics companies. Just recently, Amazon announced its entry into manufacturing as a service provider - by launching a mass 3D printing service. Many of these companies will push into manufacturing without actually building physical production capabilities. They will rather outsource these steps, thereby driving value through an exemplary use of *Agile Collaboration Networks*.

Start-ups & niche players

The disruptive impact of digital technologies in Industry 4.0 offers various entry opportunities for new players. Start-ups will build business models that focus on very specific solutions among the Industry 4.0 value drivers. Case studies on how manufacturing markets can be successfully entered by leveraging digital know-how can already be observed today: Shapeways provides 3D printing marketplaces and services, oDesk offers a digital collaboration platform for global teams, Cassantec delivers predictive maintenance solutions and Blue Yonder has developed comprehensive predictive analytics methods enabling automated decision making.

Established manufacturers

For now, established manufacturers will continue to hold the industry's core competencies and we expect them to dominate the Industry 4.0 market in the foreseeable future. However, they are under intense pressure to develop digital skills and smart value propositions to successfully compete under these changing market conditions. Established manufacturers should anticipate this development, and make cooperations and acquisitions an important element of their strategy. In order to survive in the next industrial era, they need to leverage the value drivers associated with Industry 4.0 in order to extend their established value proposition both up- and downstream through value-added services and *Smart Products*. We already witness this development today, as more and more machine manufacturers become a vital part in their clients' day-to-day operations. Alternatively, they transform their business to selling data instead of physical products, which become a mere door-opener and source for this data.

The Way Forward – Transforming Towards Industry 4.0

Achieving Industry 4.0 will be a process of comprehensive Digital Transformation. The first hype around it has already triggered hectic activities among many manufacturing companies. While companies attempting to implement state-of-the-art digital technologies ad-hoc might realize short-term benefits, they are likely to fall short of their ultimate goals. Digital Transformation is not a quick-fix solution but a long-term commitment and strategic imperative. Based on our project experience, we recommend manufacturers to embark on a six-step journey towards Industry 4.0.

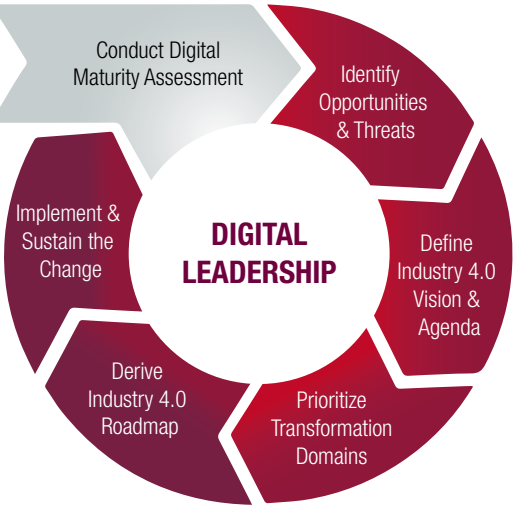
Conduct a digital maturity assessment

First, manufacturing companies should undertake a comprehensive digital maturity assessment. Organizations need to develop a transparent view on their strengths and weaknesses. A deep understanding of the status of digitization in the organization is the starting point for the journey towards Industry 4.0.

Identify the opportunities and threats in your Industry 4.0 environment

Once organizations have a clear perspective on their digital maturity, they need to explore the corporate environment for opportunities and threats triggered by the fourth industrial revolution. The exploration of altering customer demands, competitive dynamics and digital best practices should be the starting point for identifying the value drivers most relevant to the organization. Manufacturers need to understand the factors which will shape their future Industry 4.0 environment.

Figure 16 - Basic steps for initiating Digital Transformation



Source: Capgemini Consulting

Define your Industry 4.0 vision and strategy

Based on these analyses, companies have to develop a clear vision for their place in the next industrial era. This vision needs to provide a comprehensive view on how the company aims to do business in the future. It is critical that this vision is accepted and shared by all executives – a prerequisite for a clear top-down communication and a successful implementation.

> Digital Transformation is not a quick-fix solution but a long-term commitment and strategic imperative

A vision for Industry 4.0 provides the basis for deriving your strategy in a digitized manufacturing business. Company leaders should design the strategy around a clear idea of how value will be created in the future. Short- and long-term objectives need to be defined and commitment to them ensured.

Prioritize the transformation domains

Next, the organization should prioritize the transformation domains. Realizing Industry 4.0 will certainly be a complex journey, but depending on the required level of integration with existing core business processes and systems, some domains will be easier to transform than others. A prioritization matrix helps in identifying quick wins on the path towards Industry 4.0.

> Considering the extremely high innovation rate among digital technologies, manufacturing companies need to continuously challenge and adapt their transformation path

Derive the roadmap towards Industry 4.0

Based on this, a roadmap towards Industry 4.0 then has to be created containing details by transformation phases. This roadmap helps to make the journey tangible and is built on common actions set by management, business representatives and IT.

Implement and sustain the change

One of the biggest hurdles manufacturers will face during the implementation of their roadmap is to change the traditional understanding of roles and responsibilities, where IT is mostly seen as a service provider. Digital leadership will be crucial in promoting IT as a business partner across the value chain.

The road to Industry 4.0 will be long, and the transformation approach originally defined has to evolve over time. With an extremely high innovation rate among digital technologies, manufacturing companies need to continuously challenge and adapt their transformation path.

In summary, it will be crucial to see the journey towards Industry 4.0 as a strategic, transformational approach. It has to represent a commitment to sustainably changing the organization's people, processes, IT, and culture in order to deliver industrial value propositions of a new quality. Now, at the outset of the fourth industrial revolution, manufacturers find themselves at a moment of unique strategic opportunity. They should start their transformation now in order to seize it.

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- Report on the progress of Digital transformation in the manufacturing industry
- Evaluation of the digital maturity across business domains
- Recommended fields of action for Digital Transformation

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- Report on the potential of Digital to drive operational excellence in the manufacturing industry
- Deep-dive on how digital technologies impact the supply chain and service delivery performance

Digital Value Networks in the Tool Manufacturing Industry

- Joint report with RWTH Aachen University on the tool manufacturing industry
- Identification of future business requirements
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- Recommendations on how to conduct the journey towards digital innovation lifecycle management

Are Manufacturing Companies Ready to go Digital?

- Report on the impact of Digital Transformation on typical challenges of manufacturing companies
- Identification of most promising use cases for digital technologies along the manufacturing value chain

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