



## Learning Objectives for This Chapter

- What is SCOM excellence?
- What types of digital technologies can be applied to SCOM?
- How can digital technologies be applied to SCOM?
- How can digital technologies improve decision-making support?
- What are the benefits and challenges of applying digital technologies to SCOM?

## 16.1 Introductory Case-Study: SupplyOn

In this case-study, we take you on a journey into the sensor clouds and consider a new perspective on how they could transform working methods within aerospace supplier networks. We will begin with the most important requirement for the integration of sensor clouds: Collaboration! Collaboration between all parties involved. Preferably via one central platform and connecting all major players within an industry. It was this core idea which a number of aerospace companies envisioned and put into practice many years ago. In a joint initiative, a central Supply Chain Management hub was launched to effectively connect all relevant players through one single jointly used system.

This SCM hub is called AirSupply and was developed by SupplyOn. Today, more than 2500 customer/supplier relationships are powered by this platform, which has matured into the standard solution in the aerospace industry for supplier collaboration. AirSupply provides the foundation for all main SCM processes such as forecasts, orders, dispatch advices and invoices to be managed in a clearly structured and highly efficient manner.

Find additional case-studies and video streams in the *E-Supplement* to this book on [www.global-supply-chain-management.de](http://www.global-supply-chain-management.de)!

As a part of this Industry 4.0 initiative, SupplyOn analyzed the existing demand and the incoming goods processes. The demand processes is already comprehensively covered within AirSupply (cf. Chaps. 3 and 6). The challenge came with the incoming goods process: how to efficiently identify supply chain disruptions, detect material damage early on and optimize the goods receipt process to ensure a stable production with the highest possible capacity utilization.

Now let's have a look at the resulting Industry 4.0 Initiative that led up to the solution and then the solution itself. In 2016, an Industry 4.0 working group was set up to collect process optimization suggestions from all departments. The most promising projects would then be piloted and developed within an implementation phase of 90 days, after which a decision would be made on which pilots would go into productive use.

Now let's go online and have a look at the piloted solutions. We started the piloting process by first identifying a specific sensitive part regularly subjected to temperature or humidity impacts during transport. This view shows where the delivery note is generated in AirSupply. All relevant fields are pre-filled with data obtained from the preceding purchase order process.

As AirSupply supports the possibility of "pairing" material to a container and a sensor, the worker can now assign, for example, 5 packets with 10 parts each to a handling unit and then scan the connected sensor number. Now the supplier only needs to enter the number of the sensor during the creation of the delivery note. All other processes remain unchanged for the supplier. This was one of the central objectives of the project to ensure the highest possible acceptance level on the supplier side.

From this point on, the parts can be monitored throughout the entirety of the transport cycle. The new SCPM (Supply Chain Performance Management) solution continually displays the position and the condition of the parts in near real-time. The data here is automatically derived from our AirSupply solution. In this particular project, the position, temperature and humidity of the parts were tracked. The temperature monitoring was important for a temperature sensitive adhesive and the moisture monitoring was used for metal parts. Tracking the position of the parts was important for two reasons: to monitor the lead time and to allow an automatic "unpairing" of the sensor from the goods upon goods receipt.

The position of the parts or the containers is displayed as well as the distance which has already been covered. The route still to be driven is displayed. The position information in conjunction with the condition information allows a quick analysis on which routes it could become problematic.

SCPM also checks whether the order and the transport are within the agreed lead time. Software evaluates the number of days remaining until the order arrives at the plant and whether or not the lead time will be exceeded. The material planner therefore has an exact overview on the current status of an order at the top of the screen.

All the data such as position and condition are stored and can be used for reporting and analytics purposes. One of the resulting reports could look like this: By simply clicking on a container type, the graphs indicate whether there has been a

violation of the defined temperature or humidity limits along the time axis. Different drill downs are implemented—in this case the analytics period can also be adjusted. The analysis of the data in this chart allows a quick identification of all orders where the lead time was exceeded, allowing for a quick identification of transport bottlenecks.

**Acknowledgement** The introductory case-study is based on the materials of SupplyOn and is written with permission of SupplyOn. We thank Ms. Cornelia Staib and Mr. Arvid Holzwarth (MBA) for their help in preparing this case-study.

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## 16.2 SCOM Excellence and Digitalization

### 16.2.1 Operational Excellence

The term “excellence” is widely used in business. This section focuses on SCOM excellence. Companies are striving to achieve excellence in SCOM, but they increasingly face severe pressure from their business environments. Outside the enterprises, numerous changes take place in the markets and with competition. In addition, there are various types of risks, such as strikes, natural disasters, political instability, or terrorist attacks that significantly influence SC resilience. An additional factor is fast changing customer needs and expectations: it is a challenge to manage and adapt continuously changing SCs, and, as a result, also necessary to redesign those SCs and operations.

“Operational Excellence” is often mentioned in close connection with Lean Thinking or Six Sigma. Ballé et al. (2017, p. 8) stated that “the aim of a Lean strategy is to learn to solve the right problems and avoid wasteful solutions.” Martin (2008, p. 605) defined Operational Excellence as “an umbrella initiative including Lean, Six Sigma, and Total Productive Maintenance (TPM),” which focuses on the systematic usage of these philosophies and instruments to provide customer value. In addition to Martin (2008), other authors looked at the aspects of Lean and Six Sigma differently when trying to answer the key question: What is Operational Excellence? Miller (2014, p.1) stated that “Operational Excellence is the relentless pursuit of doing things better. It is not a destination or a methodology but a mind-set that needs to exist across an organisation. Operational Excellence is not about perfection or performing activities. It is about providing dramatic performance improvements and financial growth.”

Miller (2014) enhanced the view of Martin (2008), because he clearly pointed out that the “Excellence” mind-set (one could also refer to the corporate culture) needs to exist throughout the enterprise to achieve financial targets. Duggan (2012, p. 28) defined Operational Excellence in one sentence with a focus on employees: “Each and every employee can see the flow of value to the customer and fix that flow before it breaks down,” and he pointed out that “it clearly defines that waste elimination and a culture of continuous improvement are not goals of Operational Excellence but rather products of it.” Furthermore, Duggan (2012, p. 27) emphasized that

Operational Excellence is “about how the operations side of the business supports business growth.”

The significant difference of “Operational Excellence” in addition to the classical Lean and Six Sigma philosophies are the incorporation mindset, culture, and organizational behavior for improving performance with the objective of securing financial growth. In this sense, Operational Excellence is an element which secures a company’s growth strategy, and thus an incremental part of Strategic Management. Operational Excellence is a dynamic and continuous ability that opens the door to competitive leadership and high profits in continually changing business environments (cf. Hossenfelder 2010, p. 14). The dynamic factor is significantly relevant at times of digitalization.

### 16.2.2 From Operational Excellence to SCOM Excellence

Operational Excellence means searching for opportunities to accelerate value adding processes, to eliminate wasted efforts, or to identify opportunities for quality improvements. However, since it affects the entire organization and global SC players, it is much more than this (Martin 2008). SCOM Excellence needs to be considered as follows:

- a change enabler for dramatic performance improvements and financial growth in line with the strategic direction;
- a philosophy of providing superior value for customer by designing attractive products and services, as well as highly efficient value adding processes throughout global SCs;
- a cultural mindset that exists across an agile organization;
- a systematic approach including Lean, Six Sigma, and Total Productive Maintenance (TPM) focusing on the continuous pursuit of doing things better.

### 16.2.3 Digitalization as New Driver in SCOM Excellence

When SCM was being introduced to the management practices, it was popular to say that “the company is as good as the SC behind it”. Christopher (2005) formulated the proposition that the competition is not between firms, but rather between SCs. Today and in the near future, specialists say that “the SC is as good as the digital technology behind it”. Moreover, a new proposition can be formulated: competition is not between SCs, but rather between the information services and analytics algorithms behind them.

- ▶ **Practical Insights** With the help of smart sensors and plug-and-produce cyber-physical systems, the stations in the assembly system are capable

of changing operation processing and setup sequences according to the actual order of incoming flows and capacity utilization (Theorin et al. 2017). In the front-opening, unified pods technology in the semiconductor industry, robots are used in real-time operation sequencing. Collaborative robots read the information about the products from sensors and tags and decide flexibly where to forward a wafer batch next (Mönch et al. 2012). Amazon recently applied for a patent for a self-learning robot, including an automatic packaging system. This robot will be able to pick-up items ordered and package them appropriately, while secure data provides the opportunity to save the ideal packaging strategy of a product. Blockchain applications to SCs are becoming more and more important. The central idea is to increase visibility and efficiency based on record keeping in the SC. New cloud-based analytics platforms such as SupplyOn Industry 4.0 Sensor Clouds make it possible to control the SC in real-time, and plan and adjust processes using up-to-date information. By simply clicking on a container type, the graphs indicate whether there has been a violation of the defined temperature or humidity limits along the time axis. The data analysis in this chart allows quick identification of all orders where lead time was exceeded, in turn allowing for quick identification of questionable transports. Resilience360 at DHL allows comprehensive disruption risk management by mapping the SC end-to-end, building risk profiles, and identifying critical hotspots to initiate mitigation activities and alert in near-real time mode on incidents that could disrupt the SC.

We are living in times characterized by market dynamics as well as technological and organizational changes. Competition is growing rapidly on a global scale: customers expect individualized products in ever shorter frequencies. Innovations are disrupting the current players and business models in all industries and services, but what does it mean when we use the expression “digital revolution” or “digital transformation”? Digitalization is a game-changer. It will lead to significant changes in business and society in terms of work conditions and consumption of goods as well as cooperation and communication in value-chains. Furthermore, compared to previous transformations, it is anticipated that fast companies will successfully compete against slow ones (BMW 2016, p. 8).

Throughout this book, the SCOM principles have been elaborated. In this chapter, the connection between SCOM fundamentals and new technology is elaborated, such as the linkage to digital or smart factors of value creation in terms of conceptualizing and implementing the Factory of Future.

### 16.2.3.1 Digital SCOM Excellence Framework

Digital technology, respectively the digital transformation, enables the introduction of intelligent factories, so called “Smart Factories”, or adjustable (adaptive) production and logistics networks. Thus, new ideas will be delivered through the implementation of Industry 4.0. In addition to this, Big Data Analytics (BDA), the usage

of robots, augmented reality, additive manufacturing (AM), or technology for tracking and tracing are factors which generate digital SC operations. All these concepts and technologies will be considered in detail in the next paragraphs of this chapter.

To develop a starting point for supporting the development of a Digital SCOM Excellence Strategy covering multi-dimensional perspectives, a guiding framework (“CORRIDOR-Model”) has been suggested (Kiehne and Tsipoulanidis 2016). The CORRIDOR-Model serves as a guiding framework for influence assessment and development of proactive or corrective actions. These lead to an aligned SC strategy which focuses on SCOM Excellence using digital technologies. The CORRIDOR-Model is composed of the following elements:

**Complexity Is Growing** Companies are facing an increasing number of new products and variants demanded by different markets. They need to cope with various information and communication channels; this requires a holistic view of the SC and the application of efficient value adding processes. As we know, the larger a SC gets, the higher the complexity.

**Overview and the Overall Transparency Are Fragmented** The SC and all relevant processes of all SC partners cannot be determined to be “monitored and orchestrated”. However, technology for tracking and tracing and supplier collaboration portals can increase SC transparency.

**Risk and Vulnerability** Some external factors can easily be predicted, and some not. Some have a big impact, and some a low impact. A SC is not immune to risk and thus it is vulnerable, but mitigation of SC risk can be achieved through reasonable means.

**Responsibility Is Key for All Players Involved** This includes compliance to codes of ethics, codes of conduct, and includes CSR and sustainability.

**Information Flow/Information Availability** Material flow and information technology are closely connected; this is relevant for suppliers, producers, customers, and partners in a SC. New technology, respectively the digital transformation, is driving change as well.

**Dynamics in the SC Environment** The involvement of and focus on the customer has led to rapidly changing product requirements according to customer needs, changing components, new suppliers, and new locations. A SC requires adaptability, respectively dynamic networks: digital technology will have to be implemented. In addition, such systems evolve through adaptation and reconfiguration of their structures, i.e. through structural dynamics (Ivanov 2018).

**Organizational Structure** Roles and responsibilities per function inside and outside (with the partners and suppliers) need to be clear and talents developed

according to the changes in the business environment. This is strongly connected to human change management.

**Redesign of the SC** Redesigning the SC in connection with (new) suppliers and partners is frequently required as part of the strategy.

The CORRIDOR-Model is a good starting point to draft a digital SC strategy with a focus on Excellence. The framework was successfully used to assess many industries, such as food, retail, automotive, fashion, aircraft producers, general merchandise, and electronics. The specific aspects will be elaborated in the subsequent sections.

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## 16.3 Development of Technology in SCOM

Centuries ago, the way people worked underwent changes in parallel to advances in technology and knowledge. Changes took place in the past, and they are also currently taking place in the business environment. To better classify these improvements, in principle four phases, or better four revolutions, can be identified (BMBF 2013).

### 16.3.1 Three Industrial Revolutions

The first industrial revolution was mechanization of the production processes. Steam and water power was used to increase efficiency during the creation of goods. After this, the principles of work separation and the electrification of the production floors took place: this is the second revolution. The combination of the separation of work-packages and electrical power helped the industry to produce in larger quantities and use moving production lines. One well known result of that era was the production of cars, such as the Ford T-Model, on an assembly line. The flow principle and product creation in well planned work-packages led to the final move from craft to mass production.

The era starting with the 1970s was characterized by the increasing usage of computer technology during the value creation processes. This information orientation of production represented the third industrial revolution. Electronics, information technology, and the ambition for automation were dominating objectives which led to e.g., computer integrated manufacturing (CIM). During these three industrial revolutions, significant improvements in terms of productivity and efficiency were made.

### 16.3.2 Fourth Industrial Revolution: Industry 4.0

Improvements did not end with the third revolution, today we are in the midst of the fourth industrial revolution, which is based on digitalization. In other words, it is the decade of Industry 4.0.

There is no unique definition of Industry 4.0. The main idea is that in the future companies will intensively utilize and connect machines, materials, tools, warehouses, transportation technology etc. in an intelligent way. This implies the formation of Cyber-Physical-Systems (CPS). Materials, machines or devices can exchange information mutually, set priorities, trigger action and help to schedule and sequence the work in process. Value adding processes will improve themselves, which means continuous improvement would no longer be precisely connected to the human being.

Most new factory concepts share attributes of smart networking (Strozzi et al. 2017). As such, Industry 4.0 represents a smart manufacturing networking concept where machines and products interact with each other without human control. SCs in such networks have dynamic structures which evolve over time. Industry 4.0 enables companies to produce customized products in small quantities. At the same time, large amount of variants and throughput can be increased, capacities can be exploited to a higher degree, and stock levels, transports, and emissions can be reduced in parallel. It is obvious that this is the outcome of Industry 4.0 and the avoidance of waste according to Lean Thinking has reached a new level that was unachievable before (Buer et al. 2018). Because it is in complete unison with the classical approach of Lean Thinking, it has also been referred to as “Leandustry 4.0” (Tsipoulanidis 2015). Industry 4.0 also significantly enables the reduction of SC risks and resilience (Ivanov 2018). These two fundamental aspects of Lean Thinking and risk mitigation offer new opportunities for achieving SCOM Excellence at the times of digitalization.

To better explain how digitalization, Industry 4.0, and SCOM fit together, a short hypothetical case is presented.

#### **A Hypothetical Case on Industry 4.0**

Imagine that you are loading a truck with fresh strawberries. To ensure product quality, the cold chain needs to be permanently monitored in the truck with the cooler (to meet customer expectations). We also know via GPS where the truck is at each point in time. With Machine-to-Machine (M2M) technology, all collected data can be transmitted in real time, because the M2M technology ensures connectivity and data transmission (it is comparable to a mobile phone with a sim card).

Now imagine that the M2M device in the truck is communicating with a central monitoring center and submits the data that is measured during the journey to a computer in this monitoring facility on a regular basis.

(continued)

The result is that the machine (truck) is communicating with another machine (computer in the monitoring center). Following that process, the cold chain can be permanently documented (this prevents the shipment of defective products). In other words, we can track and trace the shipped goods on their way. Furthermore, if the truck has a technical problem and due to that the cooling device does not ensure the proper temperature, the driver will be notified (avoidance of bad processing).

From a logistical perspective, it does not make sense to continue the journey with perished goods. Based on the GPS data, the next appropriate waste disposal station should be identified and the driver should be instructed to go there. This helps to reduce unnecessary transportation efforts.

Also, the truck will be guided to the destination using the shortest routes: it will be redirected in case there are traffic congestions. Furthermore, the next repair facility can be contacted for the maintenance of the defective truck, where spare parts can be pre-ordered and the capacity for the repair can be scheduled to ensure shortest processing time and thus highest usability and availability of the truck. This reduces SC risk, but it also means that over-processing and waiting time is reduced.

In our case, we were assuming the truck was bringing strawberries from the field to a yoghurt factory. They will need to be informed early in advance that the truck had a technical defect resulting in rotten fruit: the expected delivery of the fresh strawberries cannot take place as initially planned. The shipment of bad inventory is avoided.

Although this is a very unfavorable situation, the producing factory might be able to order strawberries from an alternative supplier or change the production volume to produce an alternative yoghurt, maybe with nuts or vanilla flavor. The competitive advantage is generated by the early use of available information that allows higher flexibility over the entire SC and value creation network and better use of existing capacities. Proactive production rescheduling also protects the SC against its vulnerability; even though SC risk cannot be fully eliminated, it can be mitigated.

A lot of the aspects summarized in the short case above are related to the availability of data generated, stored, and analyzed during the various processes.

Recent surveys by Shafiq et al. (2015), Addo-Tenkorang and Helo (2016), Richey et al. (2016), Oesterreich and Teuteberg (2016), Küpper et al. (2016), Schrauf and Bertram (2016), Gunasekaran et al. (2016, 2017, 2018), Nguyen et al. (2017), Moghaddam and Nof (2017), Hofmann and Rüsçh (2017), Choi et al. (2018), Ben-Daya et al. (2018) identified classifications of different digital technologies and their impacts on SCM. Summarizing, the implementation of Industry 4.0 in SCOM is based on two pillars, i.e.:

- *networking environment* such as Internet-of Things and Cyber-Physical Systems and
- *enabling technology* such as RFID and AM.

### 16.3.3 Internet of Things

Internet of Things (IoT) requires electronics, software, sensors, actuators, and connectivity to operate successfully. Digital technology enables the implementation of smart factories or adjustable production and logistics networks and provides further possibilities for companies such as smart maintenance or smart logistics.

On the subject of smart manufacturing, Hentrich and Pachmajer (2016, p. 155) summarized that production machines and processes are going to become more intelligent from end-to-end and will be connected. The production will be fully integrated from planning to execution on the shop-floor and production will react flexibly when changes in the sequence or process become necessary. Production systems will be more flexible and more intelligent as a result of new sensor technology, intelligent robotics, and data analysis, so that also lot size 1 and customized products can be created economically. Production will increase its ability to innovate. For example, the maintenance of production systems will be optimized through predictive analytics and remote monitoring via mobile technology, augmented reality, and 3D-printing of spare parts. In the final scenario, production will move into the cloud and become an on-demand-cloud-service.

Porter and Heppelmann (2015, p. 11) stated “We will see a whole new era of ‘lean’”. Data flowing to and from products will allow product use and activities across the value chain to be streamlined in countless new ways. Waste will be cut or eliminated. In other words: Due to the introduction of Industry 4.0, a whole new level of ‘Lean’ can be reached because the information and data that has become available now, is necessary to avoid wastes which couldn’t be avoided beforehand because of the enhanced information technology, data availability and grown capabilities to analyse generated data” (Tsipoulanidis 2015).

In sum, “Industry 4.0 will involve the technical integration of Cyber Physical Systems into manufacturing and logistics and the use of the Internet of Things and services in industrial processes. This will have implications for value creation, business models, downstream services and work organisation” (BMBF 2013, p. 14). The principles around the Cyber Physical Systems are explained subsequently.

### 16.3.4 Cyber Physical Systems

There are multiple definitions regarding the expression “Cyber Physical Systems”. According to Edward A. Lee (2008), referenced by the VDI (2013), “Cyber-Physical Systems (CPS) are integrations of computation with physical processes. Embedded computers and networks monitor and control the physical processes, usually with

feedback loops where physical processes affect computations and vice versa.” The fundamental difference between the classical automation processes and CPS is that today an open infrastructure—the Internet—is used for communication and data exchange (VDI 2013, p. 2).

Furthermore, the real and the virtual world are now connected and this is done by converting passive components into active, intelligent systems. Due to the interaction of previously passive systems with e. g. sensors or intelligent communication devices, the components are enabled to transmit data and information from the real into the virtual world, i.e. to other machines, humans for further data analysis.

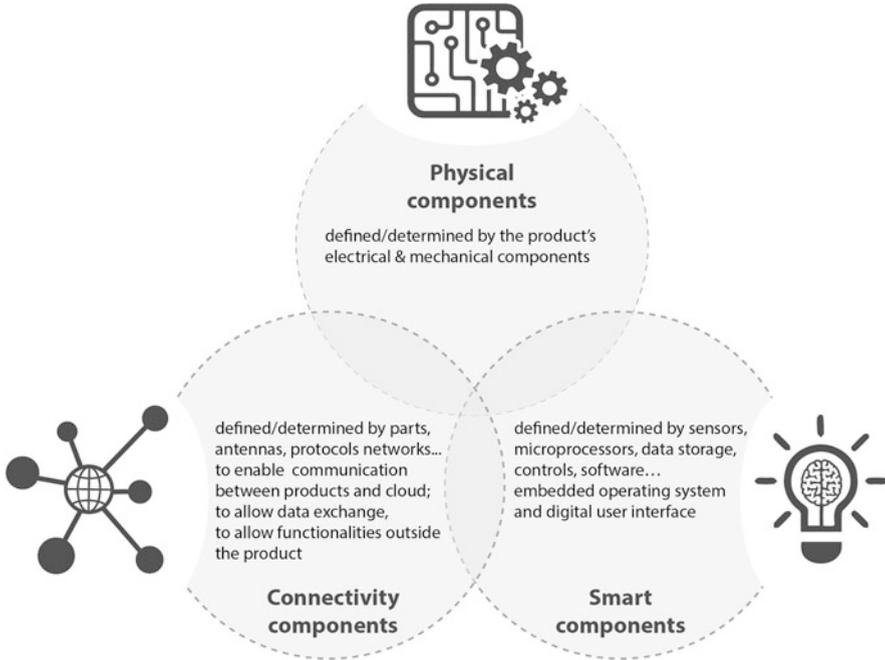
### 16.3.5 Smart, Connected Products

To understand the power of the digital transformation, the role of smart, connected products has to be clarified. According to Porter and Heppelmann (2015, p. 4), so called “smart, connected products” are a combination of three core elements. These are physical components, “smart” components, and connectivity components, as shown in the subsequent illustration. Now what does this mean? “Smart components amplify the capabilities and value of the physical components, while connectivity amplifies the capabilities and value of the smart components and enables some of them to exist outside the physical product itself. The result is a virtuous cycle of value improvement” (Porter and Heppelmann 2014, p. 5) (Fig. 16.1).

The physical components are represented by the mechanical and electrical parts or modules, such as the housing or the cooling device of a refrigerator. In addition, a smart component needs to be added to make the physical product intelligent, i.e., “smart”. Examples are sensors, control systems, actuators, microprocessors, data storage, software, the embedded operating system, and the user interface (see Porter and Heppelmann 2014). In the example of the refrigerator, a sensor is used to measure temperature to avoid icing or even to scan the items which are stored in the fridge.

To enable the refrigerator to exchange the gathered information with its environment, a connection to the outside world needs to be established. This means the smart product requires a connectivity component. As Porter and Heppelmann (2014, pp. 5–6) state: “Connectivity components comprise the ports, antennae, and protocols enabling wired or wireless connections with the product. Connectivity takes three forms, which can be present together”:

- One-to-one: An individual product connects to the user, the manufacturer, or another product through a port or other interface—for example, when a car is hooked up to a diagnostic machine.
- One-to-many: A central system is continuously or intermittently connected to many products simultaneously—for example, many Tesla automobiles are connected to a single manufacturer system that monitors performance and accomplishes remote service and upgrades.



**Fig. 16.1** Concept of smart, connected products (based on Porter and Heppelmann 2015)

- **Many-to-many:** Multiple products connect to many other types of products and often to external data sources—for example, an array of types of farm equipment are connected to one another and geolocation data to coordinate and optimize the farm system. Automated tillers inject nitrogen fertilizer at precise depths and intervals, and seeders follow, placing corn seeds directly in the fertilized soil.

Connectivity serves a dual purpose. First, it allows information to be exchanged between the product and its operating environment, maker, users, and other products and systems. Second, connectivity enables some functions of the product to exist outside the physical device in what is known as the product cloud.

### 16.3.6 Smart Supply Chains and Smart Value Adding Networks

A smart product is equipped with sensors, actuators etc. to exchange data with the environment and therefore the third criterion—connectivity—is necessary. Now how does a smart product influence SCs to become smart value adding networks? Think about smart products such as a car, an elevator, a train, or an aircraft and their connection to the SC. During their lifetime, these smart products generate data. Actually, a lot of data is generated, which has led to so-called “Big Data”.

And this is the difference—smart products generate also data regarding the user behavior, usage conditions, and the use of profiles. This helps us understand why products might fail due to certain usage conditions. This new knowledge supports the improvement of existing products, improved maintenance, and the prediction of failures prior to their potential occurrence.

It also significantly helps to improve the product development of the next generation of products. The data generated by the smart product in use also helps in terms of the monitoring of the product during its use (for example during the operation of a train, the condition of its operating devices are monitored and spare parts can be ordered and the maintenance work scheduled early before something fails). This is important for the preventive maintenance of products (i.e. planned and unplanned repairs, proactive recognition of wearing of components, defects of parts). Unplanned down-times are avoided or reduced.

Because of monitoring, the right amount of spare parts can be kept, necessary resources for replacement can be scheduled, and the availability of the product increased. This leads to the reduction of unnecessary inventory, resulting in less transportation, avoidance of over-production, etc. Thanks to the amount of data generated during the product's lifetime, indications about good or poor supplier quality might also be possible, through the prevention of defective batches. This means that sourcing processes, the process of supplier evaluation and supplier development, and thus the SC is significantly affected.

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## 16.4 Digital SCOM Framework

The technology analysis in Sect. 16.3 allows us to draw the following digital SCOM framework (Fig. 16.2).

BDA, AM, Industry 4.0, and advanced tracking and tracing technologies can be considered in regard to four major SC processes, i.e., plan, source, make, and deliver. Therefore, the areas of digital planning, manufacturing, sourcing, and logistics can be classified. Moreover, IoT, cloud technology, robots, and sensors facilitate the technical implementations of these technologies.

This classification, in line with the SCOR model (cf. Chap. 4), will be further used in Sects. 16.5–16.8 where relevant approaches concerning the usage of digital technology in SCOM will be summarized. However, it is unlikely that the presented approaches and technologies will only be applicable for one of the major processes according to the SCOR-Model. The aspect of BDA might be used for sourcing, making, delivering, or returning processes, while the AM might, for example, be used for sourcing or for making processes. Robots could be used in manufacturing, logistical, or retail processes etc. In essence, multiple applications and thus a very broad utilization and process coverage is expected, as the following sections summarize. The attempt in Sects. 16.5–16.8 is to create a framework that links digital technologies to the primary value adding processes derived from the SCOR model.

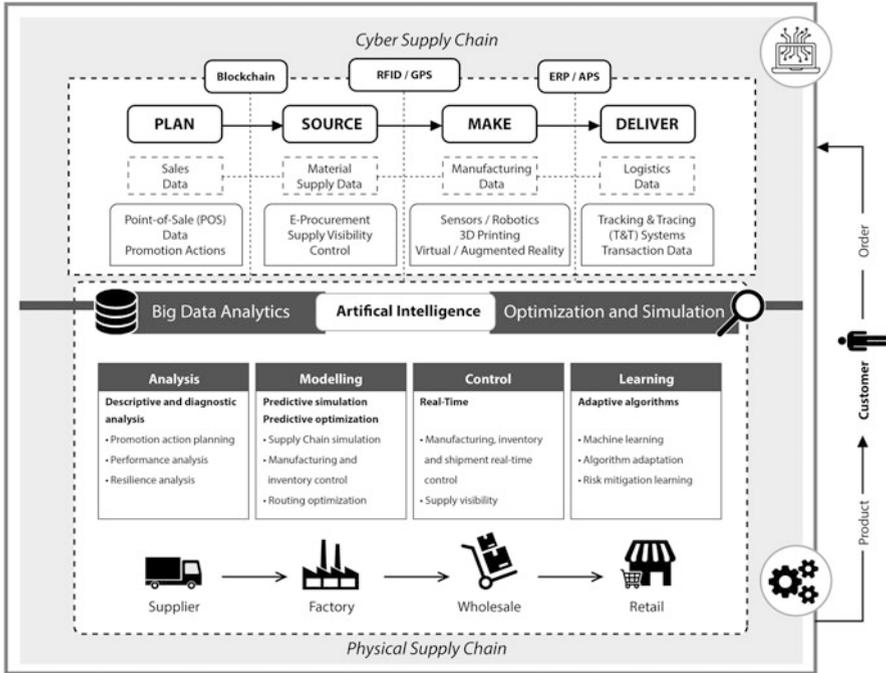


Fig. 16.2 Digital SCOM Framework

## 16.5 Digital Technology in the “Plan” Processes

In this section, a few examples are given of how planning processes can be supported by digital technologies. First, we focus on BDA. Second, the creation of a so-called digital twin in the early beginning of the product life cycle which aids in planning the SC and its operations is given as an example.

### 16.5.1 Big Data Analytics

Generally, “Big Data” is a widespread expression, which is used to summarize the large amount of unstructured or semi-structured data, which are produced day by day by companies, their devices, machines, or products in use. It requires a lot of effort to structure these data and a lot of work and expertise to analyze the data once it’s has been uploaded into a relational database. The characteristic aspect of “big” in BDA is related to the sheer amount of data, which is generated, adjusted, or modified day by day.

Big data has been characterized in literature by 5Vs: volume, variety, velocity, veracity, and value (Wamba et al. 2015, 2017). Veracity and value are particularly

important since data analysis shows the real value of big data. BDA is based on knowledge extraction from vast amounts of data, facilitating data-driven decision-making.

- ▶ **Practical Insights** Pharmapacks ships the merchandise that we expect to find in a drug store. Pharmapacks used a pricing software called “Master Mind” to increase their market share and revenue. It updates prices every 45 min and manages inventory and sales/demand forecasts. In another example, to produce cylinder heads at its plant in Untertürkheim, Germany, Mercedes-Benz uses predictive analytics to examine more than 600 parameters that influence quality (Küpper et al. 2016).

BDA has been undoubtedly the most elaborated area of digital technologies application to SCM over the last decade. Johnson et al. (2016) and Simchi-Levi and Wu (2018) analyzed the application of BDA in retail. Retailers must continuously strive to grow their revenue, margins, and market share. One method for doing this is price optimization models, which calculate the variance of demand as price levels rise or fall, and then combine this information with the relevant cost and inventory data in order to recommend prices that could maximize revenue and profits. Nguyen et al. (2017) showed that optimization is the most popular approach in the prescriptive analytics application to logistics and transportation.

BDA applications to SCM can also be seen in procurement processes, manufacturing shop floors, promotion actions in the omnichannel model, routing optimization, real-time traffic operation monitoring, and proactive safety management (Addo-Tenkorang and Helo 2016; Gunasekaran et al. 2016, 2017; Nguyen et al. 2017; Zhong et al. 2017). Nguyen et al. (2017) identified some areas where BDA can be applied to SCM in the near future. These areas include quality control in manufacturing, dynamic vehicle routing, and in-transit inventory management in logistics/transportation, order picking, and inventory control systems in warehousing. Niesen et al. (2016) and Papadopoulos et al. (2017) pointed out that BDA can help in improving SC risk management and disaster-resistance. Kinra et al. (2017) analyzed computer aided textual analysis within BDA with applications to logistics transportation systems.

Summarizing, the ability and capacity to analyze the relevant data for a company is fundamental element for achieving SCOM excellence.

### 16.5.2 The Digital Twin

The expression “*digital twin*” is used to describe when a virtual clone is created. This means that the engineers generate an item during the product development stage. This digital representation of the product is then further enhanced with additional data while the real product is made and during its usage and maintenance. The virtual and real product exchange status data are collected or measured by the sensors throughout the product’s life.

Porter and Heppelmann (2015, pp. 6–7) pointed out that a “digital twin is a virtual-reality replica of a physical product. As data streams in, the twin evolves to reflect how the physical product has been altered and used and the environmental conditions to which it has been exposed.”

One objective of the principle of the digital twin is to identify product errors at an early stage, to learn about and improve the product, and to check the performance of the product during its usage. The digital twin can therefore be used for condition monitoring and constant assessment of the status of the good while it is in operation and when it collects the generated data.

In other words, the digital and the real product form the twins which exist in parallel from the early stage of the idea, throughout the design and production simulation or production planning, until the product is really physically created and further during its usage, and until its maintenance and repair or until its removal from production. Thus the digital twin has a huge potential for the improvement of engineering, manufacturing, and for maintenance processes. The insights generated throughout the entire product life cycle and the lessons learned from beginning to end help companies to continuously improve their products and to offer additional services.

Siemens (2017) summarized the characteristics of the digital twin in the following way: “*The digital twin is the epitome of the digitalization of plants and machinery—the virtual copy of a real machine or system. And the twin is indeed increasingly proving that it can help ensure optimized machine design, efficient commissioning, short changeover times, and smooth operation.*”

This means that the digital twin provides valuable inputs for the creation of the next generation of the product and the concept of the digital twin offers the potential for new business models or services that are, for example, based on BDA.

Let us look at a mini case from practice (Siemens 2017), which focuses on the potential and achievements of the digital twin.

- ▶ **Practical Insights** The special-purpose machine manufacturer [Bausch + Ströbel](#) uses software and digitalization as the key to consistency in its engineering. It expects an increase in efficiency of at least 30% by 2020 thanks to the time saved during engineering alone. Another example is [Schunk](#), the world market leader in clamping technology and gripping systems, which is also using digitalization solutions for its electrically controlled gripping system components. This new engineering process will, it is hoped, lead to significantly shorter project timelines, faster commissioning, and a considerable increase in efficiency when building similar plants.

The digital twin’s potential to increase quality and efficiency thanks to the improved documentation of processes and machines is just as exciting. In the future, every manufacturer will know exactly which component has been installed with which features in which of its products—allowing them to provide a targeted response to problems

and to optimize processes. In its Simatic production facility in Amberg, Germany, Siemens is already using a comprehensive documentation and evaluation system and has achieved an extremely low level of errors in production.

The digital twin ensures greater efficiency and productivity in other sectors as well: with the step from integrated engineering to integrated operation, Siemens enables the process industry to build a comprehensive data model from plant engineering to operation. Digitalization ensures a shorter time to market, greater flexibility, and increased efficiency. This gives companies the opportunity to respond effectively to the volatility and diversity of global markets and to increase productivity as well as energy and resource efficiency.

**Siemens (2017): *The Magazine: Digitalization in machine building—Twins with potential***

<https://www.siemens.com/customer-magazine/en/home/industry/digitalization-in-machine-building/the-digital-twin.html>

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## 16.6 Digital Technology in “Source” Processes

Once the processes have been planned, sourcing activities need to be initiated. Of course, electronic data interchange (EDI) has been a well-known approach for managing the connection and information flow between involved companies for decades. Other means include WebEDI, which connects partners within their supplier-customer relationships, or the usage of Supplier Collaboration Portals (SCPs) for the consideration of online-shops for procurement activities.

### 16.6.1 eProcurement

E-catalogues, e-invoicing, or e-auctions can facilitate sourcing activities. Not new, but still valid is the fact that eProcurement (see also Sect. 3.1.1) is a core process within eSCM since it uses Internet Technology (IT) to facilitate purchasing processes (Wannenwetsch and Nicolai 2004, pp. 91–92). eProcurement supports companies in improving transparency concerning the supplier base, negotiations, the alignment within the company, or supporting cost-intensive and long-lasting sourcing tasks through a better information exchange. Furthermore, information technology helps to obtain more accurate, fast, and up-to-date information regarding customer needs and business processes. It also provides an overview on market changes and supports better planning, coordination, and controlling. Importantly, information technology better connects companies, suppliers, and customers and at the same time provides early warning indications. To sum up, eProcurement helps companies to reduce costs, increase sourcing security, reduce sourcing throughput

times, increase flexibility and quality, and improve the relationship between the involved parties.

In addition to the aforementioned factors, Chopra and Meindl (2013, p. 507) saw the following aspects as important trends that will impact IT in SCM:

- The growth in software as a service (SaaS);
- Increased availability of real-time data;
- Increased use of mobile technology.

They also stated that “the increased use of mobile technology coupled with real-time information offers some supply chains an opportunity to better match demand to supply using differential pricing (Chopra and Meindl 2013, p. 507).

### 16.6.2 Supplier Collaboration Portals

In Sect. 3.1, we introduced eProcurement, Vendor Managed Inventory (VMI), EDI and Supplier Collaboration Portals (SCPs) to facilitate SC processes with a special focus on VMI. It is the purpose of this section to refer to SCPs as an approach to manage the inbound and outbound flow of materials efficiently, to manage performance, and thus to describe how SCPs can be embedded in a digital SCOM strategy striving for excellence.

SCPs are successful solutions for efficiently connecting suppliers, service providers, and customers via a platform that supports transparent supplier processes. Generally, a SCP supports the management processes via a steering cockpit. This serves the forecasting, *planning*, and monitoring of the value adding activities and provides transparency and visibility of SCM activities. Furthermore, the project management processes during product development [advanced product quality planning (APQP)] can be managed to secure the smooth start of the project. The fundamental *sourcing* processes [e.g., quotation requests (RFQ)] are supported by the platform to provide *production* (status of goods received, on-time availability of materials) with the necessary materials. *Delivery* [dispatch and advanced shipment notification (ASN)] of the items is handled via the SCP. For SC managers, the avoidance of SC disruptions, the availability of undamaged components, and fast usability of the materials from goods receipt are enormously important. SCPs are powerful tools for these critical processes. Even more, the location of parts in certain containers or their status regarding humidity or temperature can also be tracked when the transmitted sensor data is processed by the SCP.

In parallel, continuous improvement processes can be run, clarity on payment processes provided, and importantly the *return* process, in the sense of managing complaints, can be part of the SCP solution. Often claim management is connected to a practical problem solving tool that enables companies to handle complaints or defects using the “8D Report” (eight disciplines report). The 8D Report consists of form sheets to document the problem solving process according to a standard routine of eight steps or disciplines (Schmitt and Pfeifer 2010). To manage SC performance, the related key performance indicators (KPIs) are tracked and allow the SCM manager to

identify deviations or problems and take corrective actions. The SCP can be seen as a repository of data and information, so that processes can also be analyzed retrospectively. Overall, the SCP helps to connect the involved parties in SCM in real-time and to improve the transparent flow of information, SCM visibility, and to enable collaboration using “what-if” scenarios for better decision making. The portals also support flexibility and proactivity, leading to improved SCM performance.

As in the example of SupplyOn (see Sect. 16.1) documented, SCPs play a fundamental role in supporting companies to deploy excellently managed digital sourcing processes. In other words, SCPs can be considered a core attribute of digital SCs.

### 16.6.3 Digital Trends for Excellence in Sourcing

New sourcing technologies to achieve excellence in procurement are considered to have a huge future potential, as digitalization is very likely the future success factor for the efficient sourcing of tasks. In particular, the following digital technologies are considered in sourcing (Decken 2018).

- *Augmented Reality* (e.g. to be used for the visit of suppliers)
- *Blockchain Technology* enables collaborative document management, payment processes, digital signatures, and documentation.
- *Data and Text Mining* helps to analyze texts and data using algorithms.
- *Digital Data Management* recognizes mistakes and errors, sorts, and excludes inactive datasets.
- *Enhanced Procurement Platforms* can be used for the sourcing processes of personnel or technical services.
- *Identification of Sourcing Synergies* using software or artificial intelligence
- *Artificial Intelligence* for the imitation of human interfaces within the sourcing processes (e.g. for the reading, analysis, and evaluation of PDFs or Excel-Tables)
- *SCM Security Rating* as assessed and evaluated by artificial intelligence
- *Smart-Contracts* to support automated contract adjustments in case of changing parameters

### 16.6.4 Blockchain

Initially, the Blockchain concept was developed to secure the financial transactions of the crypto-currency Bitcoin. Recently, the applications of Blockchain technology have begun to revolutionize different aspects of SCOM. The central idea is to increase visibility and efficiency based on record-keeping in the SC. Blockchain applications to SCOM become more and more important to enhance the scale and scope of digital processes along with creation of information pipeline systems and SC finance applications (Hofmann et al. 2018).

A Blockchain is a decentralized database that exists as copies in a network of computers. It is a chain of blocks, because the data and information stored is

captured in blocks. It is also a platform to execute the so called ‘smart contracts’ as transactions. The list of all transactions is stored as copies throughout all further involvements on numerous computers (a network of even hundreds of computers). As a result, if an illegal or unauthorized modification takes place on one of the computers, it can be traced back for verification purposes. The copies are checked regarding their consistency from the perspective of the value (e.g., if the verification value is the same on all but one computer, the manipulation is detected). Thus, the Blockchain is a technology that cannot be manipulated. Participating organizations benefit from high visibility through a secure data sharing mechanism, enabling them to plan with a greater certainty. Blockchains store the data about the location of assets at any point in time, the ownership or the custodianship of assets, and their transactional status.

The Blockchain, a relatively simple technology, is expected to be used extensively in sourcing processes, e.g., for contract management, archiving of customs documents, certificates at deliveries, or for patent management. Contracts in SCs often involve multi-party agreements, with regulatory and logistical constraints. Further complexities may arise from operations in different jurisdictions, as well as dynamic features embedded in the contracts. The flow of information in an SC plays a critical role in the efficiency of the operations. Regulatory processes (e.g., customs) can be expedited using Blockchain by improving confidence in documentations. This, in turn, can result in reductions in wastage, risk and insurance premiums.

- **Practical Insights** In the food industry, it is of critical importance to establish confidence in food safety through accurate and comprehensive documentation of the production process. This includes the location of ingredients’ production, as well as methods of processing and distribution. On this frontier, Dole, Driscoll’s, Tyson, and Nestlé are collaborating with IBM to develop a Blockchain for the food supply system. Among the issues the companies are looking to address is food contamination. IBM and Walmart are also researching how to increase food safety control in the SC using Blockchain technology (IBM 2017).

In SCOM, Blockchain is also being used for SC contracts, which often involve multi-party agreements, and regulatory and logistical constraints. Further complexities arise from operations in different jurisdictions, as well as the dynamic features embedded in the contracts. The flow of information in a SC plays a critical role in the efficiency of operations. Regulatory processes (e.g. customs) can be expedited by improving confidence in documentation. This, in turn, reduces waste, risk, and insurance premiums. IBM and Maersk are collaborating to create trust and transparency in global SCs (IBMblockchain 2017). They are developing a distributed contract collaboration platform using Blockchain technology. Maersk estimates that shipping a single container of flowers from Kenya to Rotterdam requires nearly 200 communications. How can the efficiency of the global SC be improved? In their approach, each distinct entity involved in the transaction is allowed to access this system. Shipping from the port of Mombasa requires signatures from three different agencies and six documents, the smart contract will

automatically generate after the system receives the signatures. Simultaneously, when documents about inspection, sealing of a refrigerator, pick up by the trucker, and the approval from customs communicated to the port of Mombasa are uploaded, all participants can see the data, allowing the appropriate entity to prepare for the container.

Blockchain technology provides a global tamperproof repository for documents and shipping events, and all the data are secure and transparent. Because of this, third-party intermediaries can be eliminated, resulting in efficiency, low costs, less delay, less fraud, and the possibility to have private networks. Additionally, it can also increase customer and partner trust. Blockchain technology can facilitate a truly digital SC.

### 16.6.5 Robotic Process Automation and Artificial Intelligence in Procurement

Automated processing to support routine sourcing activities such as “procure-to-pay” is another form of digitalization. These kinds of activities include conducting price searches for items or making a purchase requisition. Although it is called “robotic processes automation” (RPA), it is not a physical robot made from steel that acts, but a software application that performs the tasks that are normally done by a person. It is not necessary that the RPA software does everything, but it supports a person in performing critical or relevant tasks. In other words, the processes are conducted by software robots that run necessary activities using *artificial intelligence* (AI). AI software continuously learns and shapes its knowledge using examples. The machine uses experience and feedback, which means that it is not programmed (or coded) to solve one single problem.

Where are potential areas for RPA or AI in procurement? Generally, repetitive or administrative tasks can be automated in procurement. This could be clerical activities in classical direct, as well as indirect, procurement. Processes in indirect procurement should also be assessed with regards to their potential to be electronically supported, which might reduce uncoordinated purchasing. Often the purchasing of indirect materials (such as buying external maintenance or repair services, travel booking, sourcing of office furniture, or buying indirect materials like office supplies etc.) can be digitalized or automated. The transaction costs for indirect materials are generally high, because of the difficulty of selecting goods: the requests are more randomly placed and firms do not have one system for indirect materials (see Chopra and Meindl 2013, p. 470). When individual procurement activities are done by departments in isolation, i.e. without a structured approach, it is referred to as maverick buying; a huge potential is expected if maverick buying can be limited by appropriate technology.

## 16.7 Digital Technology in “Make” Processes

Many of the digital technologies that belong to Industry 4.0 have a close connection to *make* processes, and are connected via the Internet. This is where the name Internet of Things arose in relation to SCOM. In the following section, core technologies are presented, which mainly focus on physical value adding processes, but they can also be used in other SC areas, as well as outside the industrial world, e.g. in medical care (3D printing of prosthetics or use of robots to assist staff in hospitals) or in farming.

### 16.7.1 3D Printing and Additive Manufacturing

Historically, metal subassemblies or components have often been created by casting, milling, drilling, pressing, or turning. Other examples regarding the connection of single loose parts are gluing, riveting, or welding. In this sense, Koether and Rau (2012) refer to the use of for example shaping, reshaping, separating, joining, combining, or coating processes. Historically, often material structures took their final shape by material removal (e. g. in the case of milling, drilling, or turning), which is a subtractive technology. However, there are also manufacturing processes in which material is added. In 1990, Fritz and Schulze had already referred to sintering, a process in which (simply explained) metal or ceramic powder is heated and then pressed into the final shape of the component.

According to the International Organization for Standardization (ISO, [www.iso.org](http://www.iso.org), 2017), “*Additive manufacturing (AM), also known as 3D printing, is the process of joining materials layer upon layer, as opposed to “subtractive manufacturing” methods such as machining.*”

Khajavi et al. (2014), Holmström and Gutowski (2017), Feldmann and Pompe (2017), Li et al. (2017) described the applications of AM to operations and SCM. Those applications reach from spare part logistics to redesigning global SC production and sourcing strategies. The core of AM applications to SCM is the use of 3D printers at different stages in the SC to increase manufacturing flexibility, achieve shorter lead times, increase product individualization, and reduce inventory.

- ▶ **Practical Insights** UPS and SAP developed a joint technology which allows UPS to manufacture items using 3D printing directly at the distribution centers. This contributes to a faster and more efficient SC. Such an integration of production, sourcing, and distribution is also positive for increasing the speed of reactions to possible disruptions in the SC. In another example, Adidas Speedfactory has introduced the innovative technology of 3D printing to its production process, taking the next step towards fully high-tech and automatic manufacturing. The *Speedfactory* is based on an automatic production process to allow manufacturing to

move closer to consumer markets while producing faster than ever before.

Previously, the main manufacturing facilities of Adidas were located in Asia, most of them in China, Vietnam, and Indonesia. Under these conditions, the delivery of finished sneakers to Germany took about 3 months. By building the new Speedfactory in Ansbach, Germany, in an area belonging to the German industrial company Oechseler, the completion time of one pair of sneaker was reduced to five hours. Having a Speedfactory located in Germany, Adidas is now able to adapt production more intensively to customers' demands and wishes.

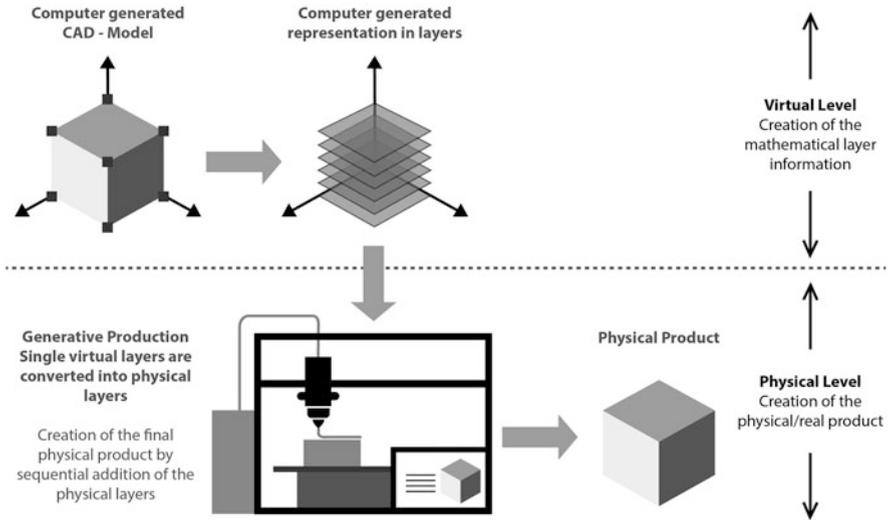
In high contrast to the foreign production facilities, production processes at the Speedfactory are almost entirely automatic, with half a dozen machines being part of the shoe manufacturing. First, a knitting machine produces the fabric used for the sneaker's surface. Using a laser, another machine cuts the fabric into the correct shape. Simultaneously, the shoe sole is put together from plastic on the other side of the factory. With 160 employees working at the Speedfactory, the overall production process requires fewer personnel than usual. In 2017, the Speedfactory started mass producing with a planned annual outcome of 500,000 pairs of sneakers. Initially, the Speedfactory will cover the production of more expensive and complex sneaker models, such as running shoes, to achieve higher quality (Welt 2016).

The advantages of such a project are numerous. Storage of finished goods becomes less important and even unnecessary since the Speedfactory, which is local and fast, can produce the exact number of shoes that is actually sold. In addition, personalized models can be delivered much more easily and quickly to customers because of the short distances. Another economic advantage of the Speedfactory is an increase in efficiency because of the ongoing work of the machines. It is important to mention that AM allows the creation of structures in ways which were never possible using traditional production techniques. Furthermore, AM allows the simplification of structures to create completely new component geometries, reduce the number of parts, and combine multiple parts into one. AM also is a key technology for reducing the weight of the components through geometry, which also helps to reduce the amount of material needed.

Companies from various industries, such as automotive, aerospace, defence, medicine, consumer goods, or agricultural tractors consider AM in various areas (D'Aveni 2015). In general, they see major potential for AM in the creation of tools, components with functional integration, replacement parts, and the customization of mass products.

According to Müller and Töppel (2014, p.7), it is common for the additive or generative manufacturing processes, as they are also called, to follow the sequence shown in Fig. 16.3.

Müller and Töppel (2014) showed that a 3D-CAD volume model is a prerequisite for all generative production processes. This 3D model is sliced into several thin virtual layers using special software. Then, the final product is created in a generative



**Fig. 16.3** Principles of generative production processes (based on Müller and Töppel 2014, p. 7)

or additive process in which volume elements are added generally in subsequent layers and the final product is created. Materials used for additive production processes include metals, ceramics, or plastics.

For SCOM, the core of the AM applications to SCM is the use of 3D printers at different stages in the SC to increase manufacturing flexibility, achieve shorter lead times, increase product individualization, and reduce inventory.

## 16.7.2 Virtual Reality and Augmented Reality

In the previous section on digital technology in the sourcing process, it was mentioned that augmented reality is a potential tool to prepare and assist procurement team visits to suppliers. In order to understand that striking digital innovation, let us look at the concept of Virtual Reality (VR). VR is computer generated reality. Like many universities, the University of Sheffield ([www.sheffield.ac.uk](http://www.sheffield.ac.uk)) operates a VR-Laboratory and they summarized that “Virtual Reality is a technology which allows interacting with a 3D computer-simulated environment as if it was real, whether that environment is a simulation of the real world or an imaginary world.”

The user enters this virtual environment be either wearing VR-glasses or similar devices like a head-mounted display. In the industrial environment and often in the early stages of product development, the user enters a 3D cinema which is a so called CAVE (Cave Automatic Virtual Reality).

The CAVE is used when products are designed and the engineers, planners, and operators want to assess functionalities, tolerances, and accessibility or even check assembly processes. The CAVE is used for example in the automotive, railway,

aircraft or turbine industries. VR-glasses are used for training purposes for logistical processes. The operator wears the VR-glasses and carries hand-held controlling devices. What is shown through the glasses is a completely virtual world, and the user can practice picking and kitting processes. The quality of the virtual representation is fascinating, as practical experience shows. Using VR, it is possible for the automotive industry to share best-practice solutions from one site to another, or train new employees very efficiently.

In contrast to this, it is important to understand the concept of Augmented Reality (AR). AR is a technology which adds a computer-generated image onto the user’s view of a real environment. The AR technology converts data and their analyses into pictures and animations, which are then added to our real environment (see Porter and Heppelmann 2018). In this way, AR enhances (in this sense augments) a real view with an unreal additional layer: digital information or visualization are projected on what the user practically sees. This can be compared to information that is written on a window and the user looks through this window into the real environment. As Westerman et al. (2014, pp. 247–248) summarized “augmented reality meshes real-world environments with additional data and presents a revised environment with computer-generated sensory forms such as sounds, graphics, and video. [. . .] Augmented reality will also change your internal processes.”

AR is already being used in production today, where operating instructions are displayed in the logical sequence of the assembly processes or to enhance maintenance processes, where a service operator receives instructions about what to replace in which sequence by looking at the defective component. AR is also used within logistical processes, where the pick worker or forklift truck driver receives enhanced information by looking through a device (like an AR glass) which shows which shelf to pick for which item in which quantity. The expression “smart glasses” is used for an AR device that is worn like a pair of eye glasses. In the medical field, AR is used to educate future medical doctors for surgery, for example. For SCOM, the technology of Augmented Reality surely contributes to the generation of competitive advantage while value adding transformation processes take place.

### 16.7.3 Robotics

The term “robot” was coined by Karel Capcek in 1921 (Brynjolfsson and McAfee 2015, p. 39). A robot is an engineered machine, which interacts in the physical world of factories, warehouses, or offices to increase efficiency or perform repetitive, monotonous tasks. In the medical environment, robots can assist nurses, for example, to avoid heavy activities that are not ergonomic, such as when patients need to be lifted. Robots are also used to perform extremely dangerous tasks, e.g. when bombs are deactivated (bomb squad) or when unknown territories like buildings need to be entered.

According to Robot Institute of America “A robot is a reprogrammable, multi-functional manipulator designed to move material, parts, tools, or specialized devices through various programmed motions for the performance of a variety of tasks” (Robot Institute of America 1979, see Gupta and Arora 2013, p. 309).

Brynjolfsson and McAfee (2015, p. 39) referred to the three laws of robotics:

- A robot may not injure a human being or, through inaction, allow a human being to come to harm.
- A robot must obey the orders given it by human beings except where such orders would conflict with the First Law.
- A robot must protect its own existence as long as such protection does not conflict with the First or Second Law.

The robots commonly have three main characteristics. First, there are the sensors, which support the gathering of information about the robot's environment. Of course, there are various types of supporting devices employed to guide the robot's behavior and its actions, such as the use of cameras, microphones, thermometers, or accelerometers to mention a few. Second, are the actuators (e. g. electric motors, hydraulics, pneumatics etc.) and effectors. These might be the tools at the ends of the robot's arms like pliers, hammers, screw drivers, spot-welding device, and motors for manipulation or handling devices, or lights or speakers. In other words, the actuators are the parts that activate the machine to perform the real value adding work. Third, there is also the control system for each robot, which can be considered the center for its artificial intelligence.

It is expected that the total number of industrial robots will be above 3.05 million by 2020, as compared to 1.828 million in 2016 according to the World-Robotics-Report 2017 (VDI Nachrichten 2017, p. 3). Furthermore, it is expected that the annual growth rate will reach 14%. The main reasons for the increased demand for robots is the need to produce with higher flexibility and to be able to better react to customer needs in shorter cycles. Traditional customers of robots are the automotive, retail, electronics, and logistics industries, who have been using robots for decades. Additionally, small and medium sized companies are increasingly using robots in their operations.

According to Statista (2017), the tremendous growth in sales of robots is largely driven by the **automotive sector**, which accounted for over 100,000 new installations in 2016. As a consequence, **robot density** is particularly high in those countries that have a strong automotive industry. For example, in Japan, there are 1562 industrial robots installed per 10,000 automotive employees, as Statista (2017) identified.

A typical and classical example is the production and assembly robot. The robots integrate strength and flexibility to assist in production sites for electronics, metal and machinery, rubber and plastics, food and beverage industries as well as the pharmaceutical and cosmetics industry. Historically very these robots are fixed and immobile installations, but in the future moving robots in the shape of snakes or spiders will be developed, so they can be very flexibly used, e.g. a crawling robot to conduct welding processes in aircraft production.

Another example is the assisting robot in a car garage. Such a robot would bring wheels, bolts, and tools to the operator. The non-value adding and heavy work of searching, motion and movement, bringing, and lifting is done by the machine, while the value adding tasks of positioning, fitting, fixing, and checking are performed by the skilled operator who can perform the task under much better and more ergonomic working conditions.

In this context, the expression *Cobot* needs to be mentioned, as increasingly the human being and the robot perform tasks in cooperation: they actively collaborate. This is how this term was coined: it is used to describe the collaboration of a robot with a human, thus called “*Cobot*”.

A similar scenario is valid for hospitals, where the medical staff is assisted by a robot lifts the patient, when a medical treatment is required, or for drawing blood from the patient. Mini robots can also be swallowed and then be moved in an externally coordinated way through a patient’s body for wound detection.

Robots are also used in farming or agricultural. For example they are used to prune vines in the vineyards (vine-bot) or to assist in pulling lettuce from the fields (lettuce-bots). Robots can also be used for cutting or harvesting crop. In an enlarged scenario, where you have (autonomous) agricultural tractors or other devices that communicate with silos and the monitoring center, the expression “smart farming” is used to describe a system of connected agricultural machines that perform tasks, run diagnosis, provide fertilizers, and are externally monitored. Smart farming goes far beyond the pure use of robots.

On construction sites, automated bulldozers might be guided by the pictures taken by a *drone*, i.e. a *flying robot*, or an “unmanned aerial vehicle” (UAV). During construction work at a site, the quality of the work performed can be monitored and documented. How many times the construction machine compressed gravel to secure a certain contractually required density or how often certain areas were bulldozed can be recorded.

Of course, drones can be used for more than elevated observation of construction locations during value creation. They can be used to perform replenishment of items or for intralogistics processes. This will be introduced with examples of other machines using the digital technology to support delivery processes in the next section.

In retail or warehousing, intelligent robots are also used to assist in cycle-counting (also in supermarkets) or in logistics for picking and kitting processes. Very popular examples are the *Kiva-Systems* warehouse robots, which bring the items from the shelves to the picking and kitting worker, increasing productivity.

These were some examples of how robots can support “make” processes. Other applications will be discussed in the following chapter on technology in “deliver” processes according to the SCOR model.

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## 16.8 Digital Technology in the “Delivery” Processes

Smart connected products have enabled companies to rethink their entire value chain and have supported them in increasing efficiency in planning, sourcing, making, delivering, and returning products. How is this connected to the subject of smart logistics or the use of digital technology to execute delivery processes? Smart logistics is an approach for connecting transportation devices, vehicles, products, materials, pallets, and load units. Using digital technology and data analytics, tracking and tracing can be performed and companies can optimize routes and loads per shipment. This section is focusing on the investigation of smart logistical devices and their primary application in delivery processes in SCOM.

### 16.8.1 Drones or Unmanned Aerial Vehicles

A drone is a *flying robot*, or an unmanned airplane or aircraft that can be remotely controlled or reach a destination autonomously under using software, known geographic coordinates, embedded sensors, and GPS data. Formally, drones are unmanned aerial vehicles (UAV) or unmanned aircraft systems (UAS).

With regards to SCOM, drones can also be used for the transportation of goods and packages. This might be to deliver goods to areas that are difficult to reach and to ship ordered packages to customers to secure last-mile delivery. In 2017, drones were tested by UPS to carry packages from the delivery truck to the house of the customer (SupplyChain247 2017). Amazon tested the delivery of their goods from a flying warehouse to the customers by drone.

Drones can also assist in conducting cycle counting or checking inventory. For this, the flying robots are equipped with an RFID reading device. As the development of drones, like that of robots, is taking place rapidly, it is only possible to provide an inspiration for drone use within this book.

### 16.8.2 Smart Driverless Transportation Systems

Driverless transportation systems (DTS) are mainly used in intralogistics and the warehousing. Such DTS increase safety during loading and unloading of materials and finished goods. These devices assist operators in every step from goods receipt and storage to order picking and preparation for shipment. In addition to the classical driverless transportation devices have been used decades, smart features are related to their precise positioning, guiding, route optimization, machine diagnostics, or real-time condition or loading monitoring abilities. DTS can operate individually or be coupled and connected.

Generally, DTS provide a higher reliability of operations due to a reduction in human errors, leading to higher productivity in warehousing or intralogistics and cost savings. There are numerous use cases of DTS and we will take a look at some examples.

#### Practical Example

One possible DTS application is the flexible connection of two production lines. Such a connection might be necessary for the onward transportation of a vehicle body. Bodies were previously moved from line to line via permanently installed transport stations. Any modifications are therefore expensive and time-consuming. With the use of driverless transport vehicles, however, the body is loaded at the end of one line and transported to the start of the other as if by magic. DTS technology is also used for so-called mobile pickers. This form of parts supply, which can replace fixed-route supply trains in production shops, makes it possible to deliver “just in time” or “just in sequence”.

At the Ludwigsfelde Sprinter plant south of Berlin, driverless transport vehicles are already supplying assembly line workers fully automatically with

(continued)

prepared “shopping baskets” from the logistics and picking areas. Take door pre-assembly: where parts containers were once lined up in tight rows along the production line and employees had to find, fetch, and install the parts themselves, you now only see the occasional tool wagon and data terminals. Everything else an employee needs to assemble a side door is brought by a driverless transport vehicle in so-called “carsets”, which contain the right parts and arrive at the line exactly in sequence with the respective vehicle.

A trailblazing pilot project is also currently underway at the Hungarian Mercedes-Benz plant in Kecskemét, where all materials are brought line-side for final assembly in pre-picked carsets by DTS vehicles. Not only does this eliminate walking distances for personnel, it also means that at the end one look into the “shopping basket” shows whether all parts have been installed—a further simple and effective contribution to quality assurance.

*Examples taken from the publication by Daimler AG available at the Global Media Site: “The driverless transport system (DTS): Autonomous mobility around the plant”*

These examples above from Daimler show in detail how Operational Excellence can be achieved using digital technology.

### 16.8.3 Smart Forklifts, Pallet Movers, and Cranes

Using a communication technology, the control system assigns certain pick orders and sends them to the closest forklift, which can then be maneuvered by the operator. In the case of fully automated, or smart, forklifts, the operations are performed completely autonomously, i.e. without an operator.

The Auto Pallet Movers (APM) are examples of such smart forklifts. In principle, they are an automated, reliable, and efficient solution for vertical order picking. According to the producer Jungheinrich, their APM ERC215a has a lifting capacity of 1.5 tons. APMs contribute to eliminating errors in picking and improved safety. Examples are automated signals, speed controls, the use of anti-slip technology, collision detection, and fork speed optimization. Such devices also increase safety in a warehouse by choosing the optimal speed and routes based on the environment. Smart forklifts or Pallet Movers can be equipped with additional technology such as barcode scanners and distance sensors. Furthermore, technology for e.g. freight documentation, proof of delivery, RFID identification, tracking and synchronization of delivery routes etc. can be installed.

Smart cranes have a broad set of applications, ranging from large warehouses to ports, yards, and the (un-) loading of various heavy freights. Examples for the use of (smart) cranes are related to the movement of steel coils or for paper roll handling. However, they are also used in shipbuilding, train production, and container handling, i.e. in metals processing.

Today, the companies that provide smart cranes also offer smart features or devices for the modernization or retrofitting of existing cranes with smart modules. Smart cranes are used for waste disposal or in container ports to handle containers between ships, trains and trucks. A well-known example is the so-called “smartPORT” in Hamburg, which is also called the intelligent port (HPA 2017). The HPA stated that the smartPORT is characterized by 10 key-elements:

- Navigation in Real-Time
- Green electricity from the land
- Intelligent switching points
- Mobile all-purpose sensors
- Smart maintenance
- Virtual depot
- Port monitor
- E-mobility in the port
- Parking for professionals
- Renewable energies.

At the container terminal in the port of Hamburg, automated guided vehicles AGVs operate autonomously, and this is done with the help of thousands of transponders that are embedded in the floor. Besides the AGVs, a complementary SmartPORT cloud application was installed and launched in 2015—jointly developed by T-Systems and SAP (Deutsche Telekom AG 2015). It aims to improve the operational traffic and trade flow as well as the overall infrastructure by interconnecting all involved parties. In the cloud, data collected about freight, infrastructure, traffic, and location of vehicles and containers can therefore be consolidated and analyzed. Through the integration of smart logistical devices and an IT-system, the automation of the majority of container, truck, and unit load device transportation between the wharf and storage areas could be realized. According to T-Systems (2018), the developed digital transportation management solution has great potential for new value networks because of the following factors:

- Intelligent infrastructures for a faster flow of goods;
- Real-time analysis of comprehensive SC data;
- Overall platform provides a constantly updated situation picture;
- Better synchronization of dynamic logistics processes;
- Unbroken shipment tracking improves distribution planning and delivery reliability;
- Cost transparency by coupling logistics and finance systems.

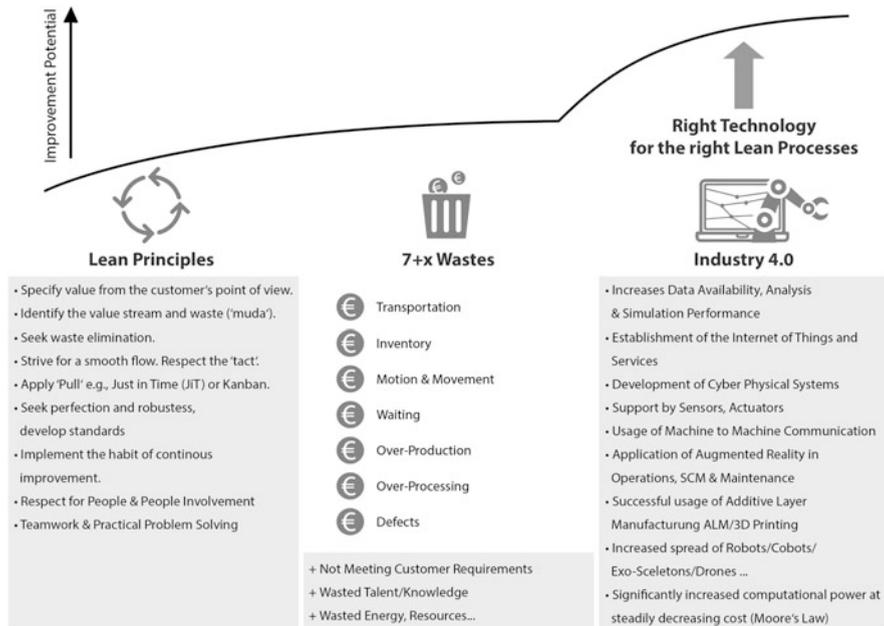
Summarizing, smart logistical devices can positively influence SCOM processes by, for example, supporting processes inside a warehouse with regards to safe (un) loading of goods, more efficient inventory management, or shorter picking cycles. Smart devices can help reduce the number of accidents, increase transport visibility, and support truck drivers. Looking at the delivery processes around the “last mile

delivery”, i.e. when the shipment is handed over to the customer, a shorter delivery time could be achieved and the environmental friendliness of the vehicles improved. In combination with tracking and tracing, this means SC visibility is improved.

## 16.9 Qualitative and Quantitative Potential of Digital Technology in SCOM

As we know from Sect. 9.5, Lean Thinking has contributed to the generation of competitive advantage in SCOM. Basic ideas of Lean Thinking are, for example, a strong customer focus, cooperation, respect, lifelong learning, and continuous improvement, which means in simplified terms that it is about generating added value for customers while preventing wasted effort. The digital transformation with its inventions and technologies offers huge potential, as this chapter has demonstrated. Thus, the combination of the digital transformation with the Lean principles is a significant factor contributing to SCOM Excellence and the reduction of SC risks (Tsipoulanidis 2017b; Ivanov et al. 2016; Dolgui et al. 2018). This is summarized in Fig. 16.4.

In this context, Scheel et al. (2015) stated that “traditional lean has lost its teeth”, which might be due to the insufficient use of technology to climb to new levels of Lean (Tsipoulanidis 2017a). As a result “digital lean is giving rise to a new era in operations excellence (Scheel et al. 2015, p. 1).” Schneider (2017, p. 36) also stated



**Fig. 16.4** From Lean to Leandustry 4.0 (Tsipoulanidis 2017b)

“Lean before Industry 4.0”: in processes and structures, an organization must be optimized according to Lean principles before applying Industry 4.0 technologies. Now, not only information and big data is available, but also the computational power required to further process and analyze it (see Westerman et al. 2014; Brynjolfsson and McAfee 2015). This enables firms to reduce wastes which couldn’t be avoided beforehand. Furthermore, it also offers new ways to analyze the generated big data, to run better and more reliable prognosis, and to implement successful measures for SC risk reduction and resilience (Ivanov et al. 2018).

### 16.9.1 Qualitative Improvements of Digital SCOM

The aforementioned improvements in SCOM with the help of digital technologies lead to resource efficient production and logistics according to the needs of the customers. Table 16.1 provides an overview on the qualitative potentials of digital technology in SCOM which uses the avoidance of the seven wastes originating from Lean Thinking as a guiding framework.

### 16.9.2 Quantitative Potential Assessments of Digital SCOM

According to a survey by Aliche et al. (2016, p. 7), “the potential impact of Supply Chain 4.0 in the next 2–3 years is huge—up to 30% lower operational costs and a reduction of 75% in lost sales while decreasing inventories by up to 75% are expected.” Another huge factor is the potential reduction of forecasting errors. Due to predictive analytics in demand planning, it is expected that forecasting errors can be reduced by 30–50%, as Aliche and his team found out.

The consulting company 4Flow presented a case at the company AGCO, where logistics costs were reduced by 28% because of the implementation of their digital supply chain concept (4Flow 2016). Overall, significant improvements are expected to be achieved over the next 10 years. Furthermore, “industrial-component manufacturers stand to achieve some of the biggest productivity improvements (20–30%), for example, and automotive companies can expect increases of 10–20% (BCG 2015).”

Other companies refer to productivity improvements of approximately 10% due to the use of RFID along the value chain. Furthermore, it was determined that increased transparency and flexibility leads to optimized use of resources. In the farming industry, up to 15% increase in productivity can be achieved (Deutsche Telekom AG 2013). Wildemann (2016) demonstrated that productivity in the automotive sector has increased by 10–15%. In addition, inventory levels are expected to be reduced by 30% due to the combination of material and information flows. As presented earlier, there is a steadily growing number of robots, or cobots (as well as BDA, 3D printing, or AR etc.) which are used across many industries. Asche (2017) presented the impressive example that the weight of a part can be reduced from 14.3 kg to 2.9 kg when it is 3D printed.

**Table 16.1** Overview on the qualitative potentials of digital technology in SCOM (Tsipoulanidis 2017b)

Category of improvement	Identified qualitative improvements
Transportation	Real-time data can be used for transportation route optimization and improved fleet utilization. Additive manufacturing AM (see also 3D Printing) leads to data exchange instead of part shipments; 3D printed parts can have a significantly lower weight, leading to lower fuel consumption.
Inventory	When better point of sales (POS) and consumption data is available, production can be done according to customer demand. Irregularly required spare parts or customized component can be printed on demand. Digital Inventory Management or Supplier Collaboration Portals can support optimization of supply networks and harmonize operations, material flows, and logistics.
Motion and movement	The human workforce can be supported e.g. by Augmented Reality (AR); to shorten the learning curve, gives guidance and reduces the potential for human errors. Machines (e.g. robots; cobots; exoskeletons, gesture-controlled logistical vehicles. . .) can conduct e.g. non ergonomic (e.g. heavy), dangerous (e.g. dust, heat), monotonous (e.g. sorting) or repetitive tasks.
Waiting	Smart operational units will determine the most appropriate production sequences and lot sizes. Robots can help to reduce machine set up times significantly. 3D printing can help to produce samples or specific tools faster. Real-Time status reports via track & trace and information regarding traffic conditions can help to reschedule routes.
Over-production	Due to more accurate sales data, better forecasting and interpretation of demand patterns for production planning and simulation will be possible. Closer cooperation with customers (co-creation), will allow the production of goods in lot size one, i.e. in the appropriate quantity/specifically small series. For individual or rare parts, 3D printing might be used.
Over-processing	Smart factories are able to configure production conditions and sequences. Items communicate independently and wirelessly with other units. Production processes can be improved, logistical replenishment processes can be initiated according to demand, and condition based maintenance work can be specifically conducted: Thus, various types of over-processing can be reduced.
Defects	Monitoring and diagnosis during operations, logistics, or maintenance can be supported. Quality can be steadily supervised according to the Jidoka and Poka-Yoke Principle (stop problematic process, solve it, avoid errors, do not ship them). Better in-process monitoring of end-to-end operational conditions (temperature, humidity etc.) increases quality throughout the value network.

Robots are getting more intelligent and thus they can become a real assistant for the classical workers and conduct 30–50% routine tasks. Another example is that due to the usage of robots for machine set up tasks, waiting time can be reduced by 50% (Continental Automotive Spain 2017).

This potential varies from industry to industry and should be considered first indications. In essence, all sources identified significant improvements due to the digital transformation in SCOM. This intensively contributes to a reduction of the

presented  $7 + x$  wastes of classical Lean Thinking. In addition, 3D printing can also be seen as a significant factor for reducing SC risk. When a supplier might not be able to deliver the goods or a supplier no longer exists, it might be a solution to follow a strategy of producing these components using AM (Ivanov 2018).

To summarize, there is a strong link between the implementation of digital SCOM technologies and improved performance. For example, a reduction of waiting time leads to higher capacity utilization. A reduction of over-produced items leads to lower inventory levels and the capability of BDA supports more robust SC processes. In that sense, Lean principles in line with SC resilience (cf. Chap. 15) are the key potentials of digital SCOM.

### 16.9.3 Possible Obstacles and Limitations of Digital SCOM

A more connected world no doubt brings many benefits – and some dangers. The previous section described the potential benefits the digital transformation will have on SCOM. At the same time, we should also consider the possible limitations, obstacles, and negative consequences digitalization might have. Table 16.2 summarizes the chances and challenges of digital technology applications to SCOM.

The chances of SCOM digitalization were analyzed in Sects. 16.9.1 and 16.9.2. With regards to limitations, the issues of skills, security, and standards are key points that need to be considered. Employees require *new skill sets* that enable them to conduct data analytics, run prognosis, operate SCPs, collaborate with robots, and so on. Engineers will need to learn new ways of thinking to design parts and products that can be 3D printed etc. Furthermore, employees on the shop floor and colleagues conducting clerical or administrative tasks might be afraid they will be replaced by steel and AI. As with all technological developments, there have been some jobs lost and new jobs created. In early days, the workers in warehouses carried goods on their shoulders and now they use a forklift truck or pallet jack. In the future, there will be staff being responsible for monitoring how the automated systems perform the work. Efficiency and competitiveness are fundamentally important, but companies also have a social responsibility: the right balance must be found. In other words, companies striving for digital SCOM processes need to critically assess cost, benefits, speed, quality, and human involvement during value creation. Ideas to strike this balance include robot taxes or the need for producers to clearly specify the ratio between human and automated value add (like a human labor depth ratio) to limit the associated number of *job losses* due to digitalization.

The *lack of standards* is also frequently mentioned as an obstacle towards digitalization. Especially small and medium sized companies show hesitance because they do not know exactly if a costly investment in the right new technology will pay off. There is no right answer to this subject. It is more the case that the aspect of standards and standardization needs to be assessed when digital strategies are drafted and respective decisions are going to be taken.

Another crucial subject is related to limited trust in security and cyberattacks. Companies carefully observe *data security* issues, data theft, attacks, dependence on

**Table 16.2** Chances and challenges of digital technology applications to SCOM

Digital technology and enablers	Chances for SCOM	Challenges in SCOM
Predictive analytics, Big Data	Increase in promotion action quality Better demand forecasts Routing decision optimization Supply chain visibility, risk and resilience analysis Better customer experience promotions Reduction in demand risks Reduction in information disruption risks and better quality of contingency plan activation	Data transparency and safety Coordination complexity increase in cross-channel logistics Higher time risks because of increases in coordination complexity
Industry 4.0, IoT, smart products, robotics, augmented and virtual reality	Customized production system at the costs of mass production Individualized products and higher market flexibility Risk diversification Higher responsiveness Shorter lead times and better capacity utilization Real-time manufacturing monitoring	Radical changes in SC and manufacturing process organization Reduction in number of SC layers New locations close to the markets Re-qualification of employees, re-design of facility layouts Data security
3D printing, additive manufacturing	Flexibility increase, Product variety, Shorter lead time Efficiency increase in MRO inventory control Reduction in demand risks	Increase in design and control complexity Higher exposure to information security risks Higher supply risks if disruption happens in the upstream SC since no intermediate inventory in between the stages
Advanced T&T technologies, RFID, sensors, Blockchain	Real-time identification Real-time material flow tracing Increase in data quality Improved transaction coordination Reduction in information disruption risks and better quality of contingency plan activation Reductions in supply and time risks due to real-time coordination if activating the contingency policies	Increase investments in ICT Data security

information technology, correctly working algorithms and so on. Managers raise the question: If all my data is stored in a *cloud* that is hosted by an external company, what are the possible risks which are connected to that? Again, there is no precise answer. The only answer is that *cyber security* or dependence on cloud solution providers is extremely important and companies will need to very carefully assess how safe their data and information is. Thus, it is another item on the list of critical evaluations and decisions when it comes to the implementation of a digital SCOM strategy.

Another result of smart technology in value adding processes is related to the *re-design of production networks*. Companies are reassessing their industrial footprint. Companies that were initially under pressure of cost efficiency might have shifted their capacities to low cost countries in Asia. Now, as salaries and wages increase in Asian production sites, a trend of re-shoring can be diagnosed, as the example of the Speedfactory has shown. There is also a second trend that sees countries in Africa as the new global workbench, as (Sun 2017) described. Even Chinese firms consider the shift of production capacity to Africa. European companies might consider the European Balkan countries as alternative to an Asian factory (here the main driver besides the cost of production is geographical proximity, so it is not purely related to digitalization).

Finally, *business models* might also be changed in line with the implementation of new smart solutions or new service providers will appear who specialize in the industry of 3D printing on demand.

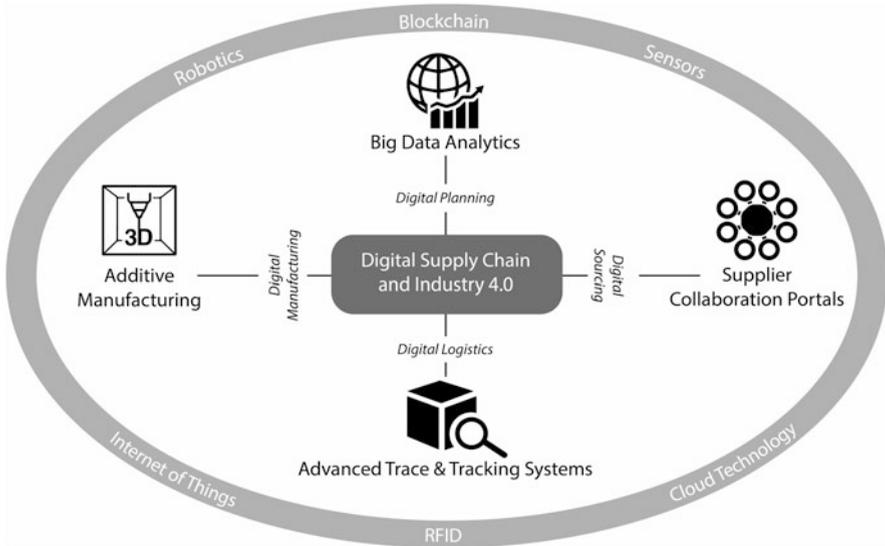
It is impossible to mention all the obstacles and limitations, but it is important to emphasize that there are two sides of the digital coin. It will be very difficult to avoid digital technology in business and SCOM, but it is important to make a critical assessment and to evaluate what-if-scenarios in the development of a digital SCOM strategy. One very important aspect though is corporate responsibility. This is why the human being should always be in the center of digital SCOM decisions.

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## 16.10 Key Points and Discussion Questions

Disruptive innovations such as digitalization and Industry 4.0 influence the development of new paradigms, principles, and models in SCOM. The Internet of Things (IoT), Cyber Physical Systems, and smart, connected products facilitate the development of digital SCs and smart operations. Digital technologies applications to SCOM include Big Data Analytics (BDA), advanced manufacturing technologies with sensors, decentralized agent-driven control, advanced robotics, augmented reality (AR), advanced tracking and tracing technologies, and additive manufacturing (AM) (Fig. 16.5).

While the individual contributors (e.g., robots, sensors, radio frequency identification (RFID), agents, modular factories, etc.) are not really new, they are becoming more practical and companies more receptive to using them to stay competitive. In addition, an attempt to interconnect these local solutions using the progress in data



**Fig. 16.5** Digital Supply Chain and Industry 4.0

processing technologies can be observed in practice. As such, this trend calls for new principles and models to support SCM of such future factories.

- Can you summarize the major developments throughout the four industrial revolutions?
- What are the main elements of smart, connected products?
- Where do you see reasons for criticism? Discuss the pros and cons of the digital transformation besides the aspects of the generation of competitive advantage.
- Where do you see potential to create new business and new jobs and where do you see risk concerning job losses?

On the technology side, ongoing developments, such as Industry 4.0, AM, smart sensors and intelligent materials, open new opportunities, but also create new challenges for ripple effect analysis in the SC. Examples of the impacts of new engineering technologies on the SC are the localization of production, high flexibility, and reduced SC coordination complexity.

This chapter has shown that there are numerous applications of digital technology in SCOM. Of course, the presented examples only reflect a small portion of the digital possibilities in SCOM and it is important to highlight that the development in this area is taking place at a very high speed.

- Can you give examples for the application of digital technologies and relate them to the processes according to the SCOR-Model (plan, source, make, deliver, return)?

- Can you explain the following terms in your own words: Big Data Analytics, Industry 4.0, Blockchain, digital twins, robots, additive layer manufacturing, RFID, and tracking and tracing systems?
- Can you connect these technologies also to the digital SCOM framework and explain how they are successfully connected as a systematic concept?
- Do you recall which suggested framework helps to evaluate a supply chain and to draft a strategy for digital SCOM Excellence?

Immediate benefits of applying digital technology in SCOM are higher transparency, increased capacity usage, cost saving, and elevated safety as well as reduced SC risk, which are all examples of achieving SCOM Excellence by using technology in the digital transformation.

Finally, we note that this chapter does not pretend to be encyclopedic and rather seeks to highlight the role of digitalization in SCOM with the objective of identifying the perspectives that can be leveraged in the near future in exploring how digital technologies can improve decision-making support and performance in SCOM.

- Make a recap regarding the potential which digital SCOM offers to reduce SCM risk and how it helps to climb new levels of Lean.

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## **16.11 Case-Study “Smart Usage of Big Data Along the Supply Chain: Big Data Analytics Between Companies, Value-Added and the Impact of Risk and Complexity Management”**

### **Learning Goals**

- Understand the complexity of big data projects along the supply chain;
- Understand pain points for suppliers, such as data conversion and concerns about sharing machine data;
- Understand how organizational restrictions play a role;
- Understand the challenges of setting the right goals and the need to have a fitting project setup;
- Understand the challenges facing suppliers who need to share some data and keep other data private.

### **Situation**

An Aerospace manufacturing Tier1 company is in a ramp-up phase for a new Aerospace program (for a cadence increase of a new aircraft model). Therefore, this Tier1 company is seeking to secure its inbound supply chain with its own key suppliers. First steps are planned to receive, evaluate, and interpret production data from such suppliers. An affected Tier 2 pilot supplier is requested to provide forecast and production progress data to the Tier1 company.

**Target**

The CEO of the Tier1 company wants to secure his supply chain, since he has to manage the ramp-up of a new aircraft program for one major Commercial Aircraft OEM. For this purpose, he requests demand and production data from his strategic A suppliers, which will ideally be available to use for his own company’s analytics. Through increased supply chain visibility, the competitiveness of the Tier 1 company in managing the ramp-up will be strengthened. He requests that the Tier 2 supplier listed above acts as the pilot supplier and shares the related production data.

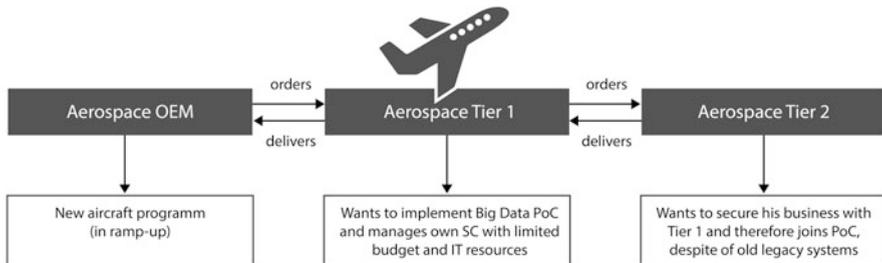
**Complication**

The Chief Digitalization Officer at the Tier 1 company has just been appointed. As budget and skilled employees are scarce, he seeks to implement a proof-of-concept (PoC) within a few months to show he can perform and reach his objectives even with limited efforts. As the IT department is facing serious bottlenecks, the development of an internal solution is not feasible as long as they are not in the lead for the PoC and receive additional resources.

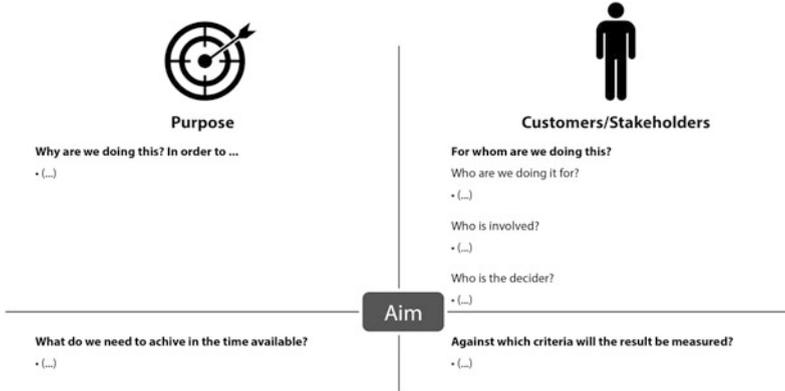
The Tier 2 supplier does not build upon standard a production system, but for years has built upon dedicated legacy systems with proprietary interfaces, such as a CSV download. The main purpose of the Tier 2 supplier is to stay in business, so he approves joining the proof-of-concept with the Tier 1 company even though the value added is questioned by some employees and the workload is already at the limit, because of the program ramp-up for the Aerospace OEM. Furthermore, the Tier 2 supplier wants to keep control of which production data he will share with the Tier 1 company (Fig. 16.6).

**Frame Conditions**

- The given timeframe for the proof-of-concept is only 3–4 months.
- The budget at the Tier 1 company is limited, but if the proof-of-concept proves successful, the board has promised to release a further budget.
- Business processes of the Tier 1 company and Tier 2 supplier (e.g. usage of forecast, before the order process starts) and IT tools (including the ERPs) are different.



**Fig. 16.6** Supply chain structure



**Fig. 16.7** Analysis framework

- Daily business will need to continue despite the foreseen PoC

**Instructions**

Organize yourselves in teams of four people (or at least three). Answer the following five questions and prepare a short (max. 10 min) presentation of the results.

Explore which interest in the Aerospace OEM drives the Tier 1 company to invest in the Big Data PoC (proof of concept). Methodology wise, please fill in the aim grid below (Fig. 16.7).

Discuss the Pros and Cons of a Make-or-Buy decision in terms of the Big Data solution in the Tier1 company. Consider not only financial factors, but also the availability of IT resources, time-to-market and collaboration factors, or if different partners with non-standardized IT tools seek to collaborate.

Discuss in which sequence the following steps (which are randomly listed below) would have to be organized to ensure a successful project. For this purpose, number the steps in the correct sequence in the column on the right (the first step is already entered).

Project steps (in random order below)	Step number
To-be analysis for future IT ecosystem/landscape	
Data migration	
Deployment of pilot plant	
Pilot productive deployment of suppliers	
Key user training	
Check data sources/Data cleansing (ensure good data quality)	
As-Is analysis of existing business processes	
Full deployment of all other sites	
As-Is analysis of existing IT ecosystem/landscape	
To-be analysis for future needed business processes	

(continued)

Configuration and setup of to-be solution in test environment	
Quality assurance for each module and related data	
Quality assurance end-to-end	
Project Kickoff/Scoping	1
Lessons learned	
Setting up change management	

1. The Tier 1 company has limited available manpower to staff the project. The project lead is a business expert in supplier collaboration, but only can invest  $\frac{1}{2}$  FTE (1 FTE = 1 full-time equivalent). In addition, the manager of the IT department can only give him limited support of 20 man days, but only for 3 months.

Explore how the shortage of available internal resources is likely to impact

- (a) Project scope
  - (b) Project timeline
  - (c) Probability of developing an in-house solution from scratch versus involving external expertise
  - (d) Probability that industry clusters (e.g. cross-company Aerospace organizations, supporting small and medium Aerospace suppliers) are involved
  - (e) Development of new advanced IT interfaces (e.g. Web Services) versus integration of in-use file formats (like CSV, Excel), with all their limitations
2. During the course of the project, not all (ideally) required data are available.

- (a) Forecast data about future customer-side demands towards the supplier are not always available.

Explore which impacts on supply chain security and related stock levels the as-is situation has and which improvements are linked to better supply chain visibility (= more transparency about future material demand, and from the supplier).

- (b) Different legacy systems at the Tier1 company in manufacturing planning and execution only provide limited data export functionalities. Concretely, only CSV files are generated once per night in a so-called “batch run”.

Explain how this bottleneck will impact expectation management towards the sponsoring management for the scope of the project.

Which restrictions apply?

Which benefits (in terms of supply chain predictability and visibility) will still apply? In this context, explore how a high OTD (on-time delivery) performance can contribute to avoid expensive stockouts.

3. Explore why the Tier 2 supplier will seek to maintain control over which production data he shares with the Tier1 company. In this context, please consider the deviating interests of the Tier 1 company, who wants production-related data from the Tier 2, and of the Tier 2 supplier, who wants to stay in business, even if in his own production, not everything always works perfect.

Then explore how the Tier 2 supplier could still maintain control process- and IT-wise.

4. Explore which benefits the Tier 1 company can expect if the project succeeds.

For this purpose, please consider Porter's Competitive Five Forces regarding industry competition.

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