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White Paper

"How Industry 4.0 Is Changing How We Manage Value Creation"

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1. Impacts of Industry 4.0 on Value Creation and the Performance Management of the Manufacturing Industry

Many manufacturing companies interpret and expect the increasing digitization and networking of man and products with each other as the Fourth Industrial Revolution. Buzzwords such as "Internet of Things", "Industry 4.0" or "Cyber-Physical Systems" are being discussed all the way up to Board level. The German federal government has bundled all its efforts concerning Industry 4.0 together in its High-Tech Strategy and declared the "integration of digitization in production processes" as a key technology for the German economy (cf. BMBF 2014, p. 36).

The term "Industry 4.0" (derived from the German term "Industrie 4.0") groups together the intelligent digital networking of different companies along the stages of value creation and the autonomous, rule-based decision-making and performance management of individual value creation functions within a company, based on Big Data analyses (cf. Kagermann et al., 2013, p. 17). This very fitting definition of the content of Industry 4.0 shows just how extensive and comprehensive it is and why it is the subject of widespread discussion.

At the same time, numerous technical concepts or applications are already being marketed under the term Industry 4.0. These innovations address different customer benefits and, in some cases, their implementation will have a heavy impact upon today's value chains. Additionally, these concepts sometimes also have a strong influence on the operative and strategic performance management of production-related value creation processes (production-related performance management), for example processes in work preparation, production, assembly and production logistics. One major change here is greater decentralization and flexibility in production performance management. This, however, conflicts directly with widespread deterministic performance management approaches, such as those which are common in established ERP systems. Figure 1 shows the main technology drivers with their associated concepts and applications, as well as the affected functions in corporate performance management.

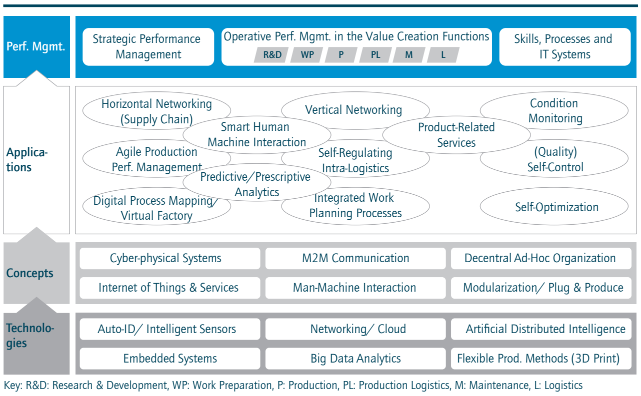

Fig. 1: Technologies, concepts and applications of Industry 4.0 and the affected performance management functions

This white paper first examines the structure of today's Industry 4.0 innovations in Germany (Section 2). Then, concrete use cases from the manufacturing industry are used to demonstrate which stages of value creation are influenced by the technological innovations of Industry 4.0 and which hypotheses can be derived from them (Section 3). Finally, the possible effects upon the performance management of production-related value creation functions are discussed (Section 4).

2. Structure of Industry 4.0 Innovations in Germany

Currently, in Germany we can find numerous research projects, demonstrators and initial applications which are published and marketed under the term Industry 4.0. Horváth & Partners have evaluated 116 of these use cases ("Industry 4.0 applications") from different industries.

The majority of these case examples are still in the development stage, while 49 of them are in the application stage and are already being marketed. The potential benefits for those users who the Industry 4.0 applications are aimed at can be broken down into four dimensions (see Fig. 2): cost reduction, flexibility, stability/ quality assurance, and increased turnover. In some cases, the examples can fall into several benefit dimensions as it is often not possible to allocate them to only one.

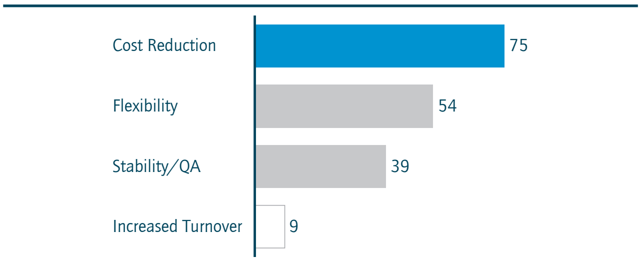

Fig. 2: Potential benefits of Industry 4.0 applications (n=112, multiple answers possible)

The main driving force for Industry 4.0 applications is the possibility of reducing costs. Three-quarters of the applications have this as their direct or indirect goal, mainly through an increase in the degree of automation and/ or improved efficiency.

Increasing flexibility is the second most common goal of the applications examined, for example through the ideal of the resilient factory, which allows companies to react optimally to fluctuations in orders and capacities. Additionally, flexible production layouts are an indispensable requirement for satisfying the customer expectation of increasingly individualized products by using reduced batch sizes.

Industry 4.0 applications often also strive to use intelligent maintenance concepts to optimize stability and quality assurance.

Remote maintenance and diagnosis can be used to service the machines used at considerably lower expense and thus potentially more frequently. Constant monitoring and evaluation of the machines enables predictive maintenance. As well as increasing flexibility, applications which increase stability also indirectly lower costs.

What is striking is that only very few applications target increased turnover, for example through opening up completely new markets with appropriate products and services or improved sales processes. This might seem no surprise as Industry 4.0 is primarily focused on enhancing efficiency through the digitization of core value creation in the manufacturing industry. However, if we think beyond the optimization of existing structures, the changes which arise from Industry 4.0 also offer a huge, disruptive turnover potential. In this context, for example, trading in production data is a rapidly growing business; this potential is by far not yet fully exploited in the current applications.

In order to make the Industry 4.0 applications currently in development market viable or to fully utilize the potential benefits of the use cases already being marketed, we need so-called enablers. These are new technologies or business models which are necessary for implementing and achieving acceptance of the Industry 4.0 applications. These enablers are, in the main, software innovations or combinations of software and hardware developments (see Fig. 3). Thus, for example, it is necessary to develop intelligent algorithms to evaluate real-time data from production. In turn, in order to collect this data we need innovations in hardware, especially the development of "intelligent" sensors capable of communication. Those Industry 4.0 applications which are mainly hardware-driven are mostly found in the field of man-machine interaction and require innovations in robotics. The small share of business model-driven applications is consistent with the small proportion of applications which increase turnover (see Fig. 2).

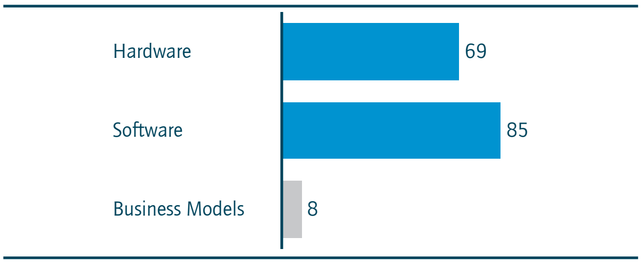

Fig. 3: Enablers of Industry 4.0 applications (n=112, multiple answers possible)

When we look at the functions involved it also becomes clear that the focus of Industry 4.0 is currently firmly fixed above all on improving industrial core value creation (see Fig. 4). Nearly 90 percent of the use cases impact directly or indirectly on the functions of production or work preparation. While the integration of the functions logistics and maintenance is also addressed (e.g. through condition monitoring), the influence on research and development is still low. However, it is here in particular that there is very great potential due to the improved flow of information from this field in the future.

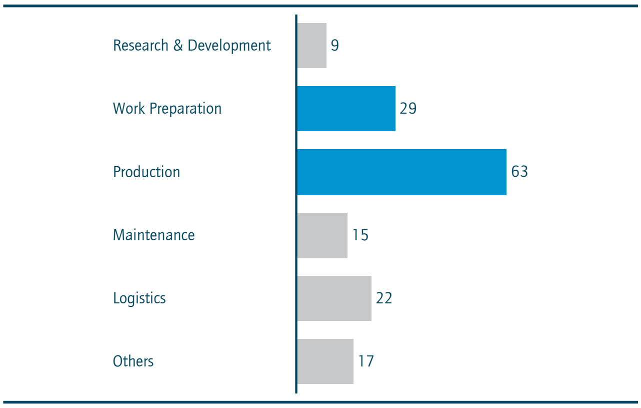

Fig. 4: Functions affected by Industry 4.0 applications (n=112, multiple answers possible)

3. Change in Value Creation by Technological Enablers

In order to show the influence of Industry 4.0 applications on value creation, this section will group the value creation-related enabler technologies into four clusters (cf. also Sauter et al. 2015) and explain them using use cases (see Fig. 5).

Cyber-Physical Systems (CPS)

In simple terms, cyber-physical systems are systems which have an interface between the digital (cyber) world and the real (physical) world. A simple example is sensors with their own IP address. Cyber-physical systems are often, however, distributed, networked ("intelligent") system elements with embedded software which use sensors and actuators to record, evaluate and store data. The CPS are integrated in wired or wireless communication networks which enable communication between technical facilities (e.g. production plants) and/or their performance management units. Thus, CPS represent an essential building block for networking in Industry 4.0.

Often, cyber-physical systems use man-machine interfaces to ensure proper communication between users and the production plants in a networked production system environment. In this context, condition monitoring through the analysis of machine data is a good example of the use of a CPS. Condition monitoring is seen as methods of monitoring machines based on up-to-date state and meta information and remote diagnosis and maintenance, for example to define optimal maintenance intervals (cf. Bayer AG in Fig. 5).

The core innovation of Industry 4.0 is the intelligent performance management of production sequences through networked plants and automation solutions based on intelligent sensors and their ability to send data. The goal of the "resilient factory" is flexible just-in-time production with optimal capacity utilization. This initiative from the company Festo AG & Co. KG aims to make the factory resilient against seasonal and capacity fluctuations caused by the broad product portfolio (cf. Fig. 5). The company Weidmüller Interface GmbH & Co. KG is also working on a solution for the intelligent automation of production facilities (cf. Fig. 5). The goal is to make production processes more flexible by developing a model-based design method for decentral automation technology components in production plants. Around 35 companies and research institutes from different industries and value creation functions participate in the technology initiative "SmartFactory^KL". The initiative is manufacturer-independent and investigates and develops different Industry 4.0 concepts in the field of factory systems.

Big Data Analytics

"Big Data" is defined as the use of partially sensor-generated, networked but unstructured data from a wide variety of sources. This is the underlying requirement for most use cases and enabler technologies. The data can be created in Industry 4.0 use cases, for example through intelligent sensors on machines and workpiece (carriers), through mobile or stationary CPS, or through classical company data (cf. Mehanna/Rabe, 2014, p.°70). The challenge here lies in intelligently consolidating and evaluating these enormous amounts of data in order to, for example, generate forecasts (predictive or prescriptive analytics). This then, for example, enables companies to analyze production data by using fact-based bases for decision-making (cf. e.g. Siemens in Fig. 5).

Digital Process Mapping and Performance Management of Real Production Sequences

The data is also used for digital mapping/ portrayal and the performance management of real production sequences in real time. Here, for example, production orders are no longer only sent back to the production and ERP systems after they are completely processed. Instead, continuous updates about the current state of processing are sent back to the systems. Wittenstein AG utilize this data in the use case "Mobile Production Management" so that production workers can access detailed planning information on production orders regardless of their location using a mobile device (cf. Fig. 5).

This enables effective access to information and speeds up the escalation process (for faults or breakdowns or capacity bottlenecks). DMG Mori Seiki AG support workplace preparation and the NC programming of their tool machines through simulation on a virtual image of the machine. This allows the production process to be optimized, and the findings are put in a central knowledge database for comparable processes (cf. Fig. 5).

Smart Man-Machine Interaction

The use of mobile information systems for employees in production, in spare parts warehouses or in production logistics is an example of the utilization of existing technologies which, through progressive man-machine interaction, make the processes more efficient and more secure. The VW conglomerate is experimenting with smart glasses in their spare parts warehouses to replace handheld scanners. ABB Ltd are investing in the use of tablets in their service functions in order to use augmented reality to make maintenance information on defective equipment available quickly and on the move. Trumpf GmbH & Co. KG are using technology platforms and online marketplaces for production-relevant data directly where the machine is located so that their employees always have access to the most up-to-date information.

These real-world examples show that every aspect of the manufacturing industry and every research institute is tackling the topic of Industry 4.0.

The changes in the value creation functions we can expect from Industry 4.0 were investigated in a study (cf. Sauter et al., 2015), and the key findings from that study are summarized in the next section of this white paper.

The changes arising from Industry 4.0 will first be noticed in the value creation functions of production, production logistics and production planning. Figure 5 illustrates the impacts of the Industry 4.0 applications presented here on the value creation functions. It can be seen that in nearly all examples there is a direct or indirect influence on today's production procedures, on work preparation, on production logistics and also on production and plant performance management.

Based on the case examples we can derive concrete hypotheses on changes in production-related value creation (cf. Sauter et al., 2015). These hypotheses are summarized in Figure 6, and details are provided in this section in order to examine their influence on corporate performance management.

Hypothesis 1: Self-Regulating Production Performance Management

Until now, the high cost of tooling and thus increased overall costs has restricted the degree of individual product customization. Making production plants far more flexible across the board will make it possible to take advantage of high capacity utilization to produce in very small batch sizes.

Festo AG have already started to implement the requirements for a "resilient factory". This requires the integration of autarkic, exchangeable process modules with standardized interfaces into the production lines (cf. Berthel, 2013). Additionally, intelligent, event-driven, self-regulating production machines are joined together in process modules. This means that products can be allocated to the appropriate machines depending on parameters such as priority, machine capacity utilization, etc., and manufactured there.

Company	Industrie 4.0 Initiative	Enabler Technologies and Clusters	R&D	WP	P	PL	M	L	S
ABB Ltd	Maintenance information can be accessed as augmented reality via tablet	▪ Mobile/ online availability of relevant data ▪ Augmented reality technology ▶ Mobile information systems			Indirect		Direct		
Bayer AG	Error prediction and diagnosis via social media	▪ Comprehensive system mapping in real time ▪ System-state identification (condition monitoring) using networked sensors ▶ Cyber-physical systems (CPS)			Indirect		Direct		
BMW AG	Networked R&D and production/ work preparation	▪ Involved departments are networked ▪ Ability to simulate manufacturing processes ▶ Digital mapping/perf.mgmt. of real production sequences	Direct	Direct	Indirect				
Daimler AG	Optimization of production logistics through traceability/CPS	▪ Sensors which can be networked ad-hoc ▪ Traceability and real-time system mapping ▪ Interface to existing CPS and logistics chain ▶ Cyber-physical systems (CPS)			Indirect	Direct			
DMG Mori Seiki AG	Work planning and NC programming via virtual tool machine	▪ Virtual portrayal of real-world work environment ▪ Ability to simulate manufacturing processes ▶ Digital mapping/perf.mgmt. of real production sequences		Direct	Indirect				
EUCHNER GmbH & Co. KG	Networked production	▪ Traceability and real-time system mapping (RFID and as-is feedback (M2M)) ▪ Intercompany networking of value creation/ supply chain ▶ Cyber-physical systems (CPS)		Indirect	Direct			Direct	
Festo AG & Co. KG	Smart Factory – Flexible just-in-time production with optimal capacity utilization	▪ Interface standards for production modules ▪ Modular/ self-configuring software ▪ Simulation of order situation and production layout ▶ Digital mapping/perf.mgmt. of real production sequences		Direct	Direct				
Fraunhofer-Institut für Produktionstechnik und Automatisierung (IPA)	Inclusion/ networking of customer in the value creation chain	▪ Big Data analysis/ handling methods ▪ Real-time portrayal/ system modelling in the planning system ▶ Big Data evaluation	Direct		Direct			Direct	
	Enabling of up-cycling through stored material data	▪ Data storage in the product across the entire lifecycle ▶ Big Data evaluation							Direct
	Smart Factory – Flexible just-in-time production with optimal capacity utilization	▪ Decentral inter-disciplinary system intelligence ▪ Ability to analyze Big Data ▶ Big Data evaluation		Direct	Direct				
HARTING Technologie-gruppe	Integrated Industry – Next Step	▪ Traceability, real-time feedback and M2M/M2W using RFID technology ▪ Vertical integration (of field level using RFID and sensors through to SAP backend system) ▶ Digital mapping/perf.mgmt. of real production sequences		Direct	Direct				
Maschinenfabrik Reinhausen GmbH	Manufacturing Execution System (MES) ›MR-CRM‹	▪ Cyber-physical systems (CPS) ▪ Interface-neutral networking of man and machine (vertical integration of ERP, NC programs and quality assurance) ▶ Cyber-physical systems (CPS)		Direct	Direct				Direct

Value Creation Functions Examined: R&D, WP, P, PL, M, L, S

Key:
Research & Development | Work Preparation | Production | Production Logistics | Maintenance | Logistics | Others
Direct Influence | Indirect Influence | No Influence

Fig. 5.1: Overview of the Industry 4.0 applications including their enabler technologies and the value creation functions affected

Company	Industrie 4.0 Initiative	Enabler Technologies and Clusters	R&D	WP	P	PL	M	L	S
Siemens AG	Smart Data in production through fact-based basis for decision-making	▪ Comprehensive collection of production data ▪ Ability to analyze Big Data ► Big Data evaluation		Direct	Direct		Direct		
	Software and automation solutions for the Smart Factory	▪ Totally integrated automation ▪ PLM software ▪ Digital mapping of the factory ► Digital mapping/perf.mgmt. of real production sequences		Direct	Direct	Direct	Direct	Indirect	
Trumpf GmbH & Co. KG	Networking of production systems within a value creation chain	▪ Automated adaptation of machine/ technology models ▪ Technology-specific ad-hoc materials sensors/ M2W communication capacity ► Cyber-physical systems (CPS)		Direct	Direct	Direct			
	Digitization/ online market place for production-relevant information	▪ Mobile/ online availability of relevant data or the possibility to access it ► Big Data evaluation		Direct	Direct				
	Online maintenance (condition monitoring)	▪ Comprehensive system mapping in real time ▪ System-state identification (condition monitoring) using networked sensors ► Cyber-physical systems (CPS)					Direct		
Volkswagen AG	Use of smart glasses in parts warehouses	▪ Mobile/ online availability of relevant data ▪ Automated visual comparison with standard processes/ requirements ► Mobile information systems				Direct			
Weidmüller Interface GmbH & Co. KG und Paul Hettich GmbH & Co. KG	Self-optimization of remolding processes	▪ Algorithm-based performance management ▪ Sensors for assessing current state ► Cyber-physical systems (CPS)			Direct				
Weidmüller Interface GmbH & Co. KG	Intelligent automation solutions for production facilities	▪ Intelligent components such as sensor-actuator interfaces or signal converters ▪ M2M/M2W communication technologies ► Cyber-physical systems (CPS)			Direct				
Wittenstein AG	Mobile production management	▪ Real-time queries for production orders/traceability and real-time modelling (DataMatrix Codes) ► Digital mapping/perf.mgmt. of real production sequences			Direct				
	Distributed plant performance management in the SmartFactoryKL	▪ Semantic technology-intelligent workpieces ▪ Automatic selection of the right processing machine for the workpiece ► Digital mapping/perf.mgmt. of real production sequences		Direct	Direct				
Würth Gruppe	Data transfer from inventory data and optical ordering system based on Kanban	▪ Traceability and M2M communication for transferring inventory data ▪ Optical ordering systems based on Kanban ► Mobile information systems			Indirect	Direct		Direct	

Value Creation Functions Examined

Key:

R&D = Research & Development; WP = Work Preparation; P = Production; PL = Production Logistics; M = Maintenance; L = Logistics; S = Others

Direct Influence | Indirect Influence | No Influence

Fig. 5.2: Overview of the Industry 4.0 applications including their enabler technologies and the value creation functions affected

Hypothesis 2: Agile Detailed Planning and Disposition

Most companies carry out central (plant) production and work planning based on the current volume of orders in a defined period. For companies with a high proportion of make-to-order in production, this deterministic production planning is reaching its limits as it is very complex to integrate the necessary data. However, a decentral event-driven production control and disposition system enables the company to react flexibly to such events.

EUCHNER GmbH & Co. KG show that networked production (IT and production technologies) can leverage potentials for optimizing and providing the required data. In contrast to reporting on the entire batch, automatic feedback on the actual units produced is used in combination with order tracking to react flexibly to new orders, production delays or other situations.

Hypothesis 3: Decentralized Work Preparation

As already described, current state data on the production machines is essential for self-regulating production performance management (cf. Siemens AG in Fig. 5). In addition to the information about current capacity utilization already mentioned, this applies in particular to "production competences", maintenance information and possibly even production costs (in the sense of hourly rates). Production competences are the possible production steps which can be carried out by machines. If M2M communication is in place, this information can be collected and processed in a central production performance management system.

Hypothesis 4: Modular Organization of Work and Machines

As multi-functional processing centers, many production machines already have several production competences today. As the trend towards greater individualization of products continues, the demand for flexible, multi-purpose production machines will also grow. The shift towards agile production systems without deterministic allocation of machines per production step means the production organization used to date must be adapted to satisfy the changing requirements. This includes, for example, the modularization of the product architecture and of the work plans. By creating modular architectures and defined interfaces, we enable greater flexibility in processing and in assembly (cf. Trumpf in Fig. 5).

Hypothesis 5: Roving Tools and Molded Parts

Molding or remolding with the help of capital-intensive tools will face new challenges arising from the increased flexibility in production. The high investment costs for purchasing or making molds and tools prevents or makes it difficult to stockpile multiple sets of the same tool for different machines and the same production step. Using intelligent tool scheduling or tool logistics, however, the tools can be delivered to the respective machines and tooled up just-in-time. In this way, for example, several laser processing centers at Trumpf share one laser source in order to maximize capacity utilization and reduce investment costs.

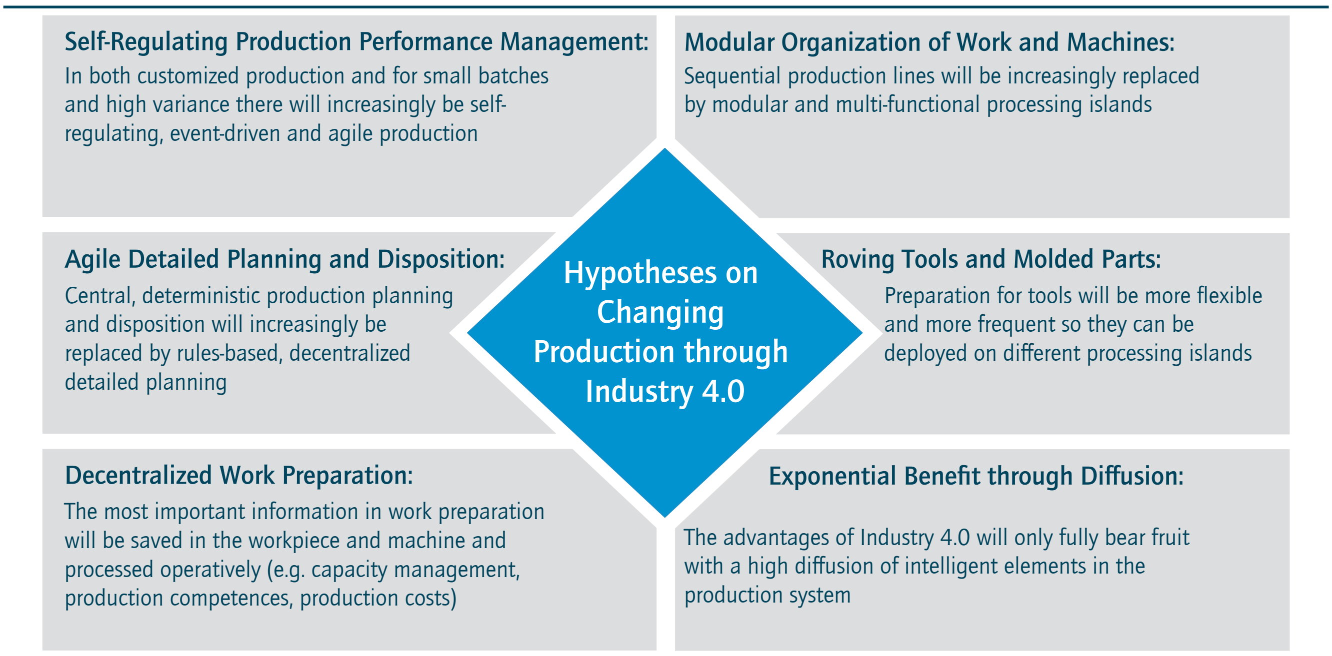

Fig. 6: Hypotheses on changing production and production logistics and planning through Industry 4.0

Hypothesis 6:
Exponential Benefit Through Diffusion

The possibilities for using decision-based production performance management in flexible production systems to react adaptively to the capacity utilization situation of individual machines are, in the best-case scenario, high. Due to the higher diffusion of networked elements, this advantage grows exponentially with the number of machines integrated into the network. This, however, also equates to high capital investment costs. As a result, decisions concerning a company's digitization and investment strategy should only be taken after an in-depth evaluation of the benefits that specific company will enjoy by increasing flexibility and after comparing those benefits with the transformation costs they would require (investments, finance plan, etc.).

4. Change in Corporate Performance Management through Industry 4.0

The CFO Study 2014 (cf. Horváth & Partners, 2015) looked into the importance of Industry 4.0 in the CFO function and individual measures. The measure with the greatest importance in this field was identified as the continuous measurement of adaptability, versatility and efficiency of the resources utilized; it is also seen as a top challenge with the greatest need for action.

As already mentioned, the operative changes brought about by Industry 4.0 have a great influence on the future operative and strategic performance management of companies. Based on the hypotheses presented in the previous section, in the following we evaluate the changes to operative performance management in terms of production and the production-related functions (cf. Sauter et al., 2015).

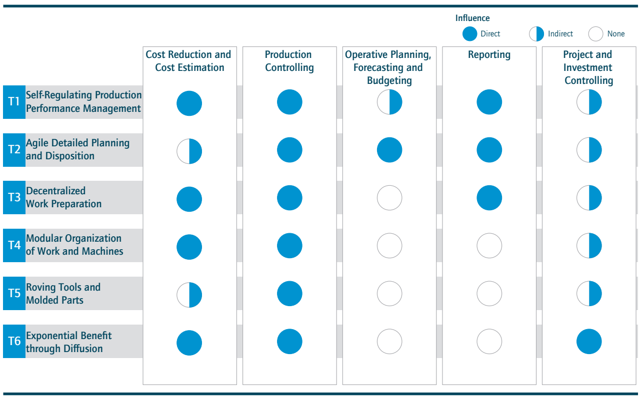

Fig. 7: Influence of production-related theses on the further development of corporate performance management regarding Industry 4.0

It is the concepts for standard cost estimation and for cost accounting and financial reporting, in particular, which must be adapted to suit the changing underlying basic information (bills of materials, work plans, changing production processes). The calculation of (standard) production costs will be made more difficult as there will no longer be complete and rigid work plans. When the workpiece finds its own way through production ("workpiece controls production"), it creates a large number of different work plans which cannot simply be integrated into the cost calculation. The performance management models which are based on the variance calculation (e.g. the difference between estimated standard or target costs and actually reported times and costs) and their interpretation, together with the corresponding measures, must be expanded. If there is only one underlying standard or basic work plan for the cost calculation, such as the work plan with the average production costs, accurate interpretation will be very difficult. Without standard cost estimation and calculation, the only yardstick for comparison is an ideal work plan.

These changes also have massive impacts on production controlling. A new method of calculating target costs can be used as a future performance indicator and comparative value as it shows other determinants for production performance management, such as current capacity utilization of the machines, priority of production order, etc. Warehousing will be managed increasingly using stochastic methods and the associated controlling will be based more heavily on forecasting. Maintenance strategies and their resulting costs will also be based on prognoses. Quality costs will be calculated directly from the machine and transmitted to the relevant functions. However, for such a system of production controlling the required data must be sent automatically to the ERP systems and they, in turn, must be able to interpret that data.

As demand becomes both increasingly flexible and increasingly volatile, this can result in planning and budgeting processes becoming less relevant, while the focus shifts more to prognoses and forecasts. The integration of new data sources, the ability to carry out Big Data analytics and predictive analytics – the derivation of structures and connections from unstructured data and the prediction of specific determinants – can partially reduce the high costs of generating information for the planning and forecasting process through automation.

In the field of reporting, M2M communication enables the approach for real-time portrayal of production and current machine states through automated real-time feedback presented earlier in this paper. Operative and financial performance management can take place more directly thanks to new methods and procedures and the time loss from data collection to data provision and the subsequent reaction will be reduced significantly. Additionally, the operative, horizontal integration of the value creation functions (suppliers/ customers) also requires the partial integration of controlling processes to controlling networks of the same partners.

Moreover, project and investment controlling must be prepared to face new challenges in order to be able to provide appropriate support for upcoming investment decisions regarding the digitization of production, the evaluation of modular concepts, or investments in tools.

What must be noted here is that the approaches to adapting and further developing the corporate performance management concepts are still only preliminary considerations. At the moment, the discussion about Industry 4.0 still focuses heavily on technical aspects, while the Industry 4.0 applications which already exist are primarily solutions for special use cases and sub-areas of value creation. There are very few real-world holistic Industry 4.0 concepts and those that do exist are still at the pilot stage (e.g. the SmartFactory^{KL}). Until standards have been established, the adaptation of controlling instruments will only take place in individual companies and step-by-step. As a result, the agenda of the CFO and CIO functions in the near future will concentrate on helping to shape the digitization strategy, on evaluating strategic investment decisions, and on the successive preparation of operative performance management for the future requirements.

5. Summary and Outlook

Today's Industry 4.0 applications focus on creating greater process integration and automation in the core value creation processes in manufacturing companies and on optimizing the resulting gains in efficiency and effectiveness. In the future, attention will shift increasingly to the step-by-step integration and networking of further value creation processes, such as product development. Despite what the name implies, the Fourth Industrial Revolution is still more of an evolution. The applications and (pilot) projects in existence to date analyze and focus on individual aspects of production processes and work. The development and marketing of more innovative products through new business models still falls short of the disruptive potential predicted by many. Having said that, the ongoing digital penetration of value creation will provide a strong boost to this development. For this reason it is important to analyze the influence on your company today in order to identify the future fields of action.

We can already see today that Industry 4.0 activities will have a far-reaching influence on value creation-related performance management. Companies would be well-advised to identify the need for adjustment as early as possible and to take active measures to master the upcoming changes.

In this paper we have presented initial approaches for adapting value creation performance management to the new environment. The hypotheses postulated here provide a framework for your preliminary considerations on Industry 4.0.

Horváth & Partners are the leading management consultants for Corporate Performance Management and Performance Optimization. We would be pleased to place our experience in concept design and implementation at your disposal.

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