Towards a Reference Model for the Use of Information Technology in Cyber-Physical Production Systems

Masterarbeit

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Name:	Hartmann	Vorname:	Nils Peter Alexander
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]		

Prüfer: Prof. Dr. Michael H. Breitner

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1. Introduction

In August 2014, the German federal ministry of education and research published the latest issue of the High-Tech Strategy 2020. Its goal is to drive innovation to “strengthen Germany’s position as a leading industrial and exporting nation.” As one development to secure Germany’s competitiveness, Industrie 4.0 is identified as a key task for the integration of information and communication technologies (ICT) into the industrial production (BMBF 2014).

The challenges of modern production are further described in the final report of the Industrie 4.0 Working Group, a consortium of industry professionals and members of industry associations. With the help of new production systems, the companies are able to meet the individual customer requirements with an increased flexibility and an optimized decision-making (Kagermann, Wahlster, & Helbig, 2013, p.16).

The term Industrie 4.0 has also become of great interest to the industry itself. In 2015, it was a major subject at the biggest industrial and ICT trade fairs the Hannover Messe and CeBIT (Hannover Messe 2015a, Deutsche Messe 2015).

> "HANNOVER MESSE 2015 has made it unmistakably clear: Industry 4.0 has arrived, and is sweeping every sector of industry."
>
> [Dr. Jochen Köckler, member of the Managing Board at Deutsche Messe (Hannover Messe 2015b)]

The foundation of Industrie 4.0 is the integration of cyber-physical production systems (CPPS) into production. These systems consist of a network of smart objects and machines that capture the environment, process data and exchange information via the Internet (Bauernhansel 2014, p.15f.). As a result, the production shifts from a static, central planned structure to a dynamic network of autonomous systems. Decentralized decisions in real-time provide the necessary flexibility to react to changes in the order specifications and the layout of the production systems, while individualized assistance systems support the employees in every aspect of their work. However, the changes are not limited to the optimization of production. New business opportunities emerge with the introduction of sensors inside the components and an increasing integration of the customer into the value network. With this, the companies need to adjust their strategy to meet the demands of the changing business processes. This includes every aspect of the organization from the product design and product lifecycle management, to the sales model. Not all aspects of Industrie 4.0 require huge investments in new production technology to ensure future success of the business, however, a successful implementation of Industrie 4.0 elements into the business strategy involves specific know-how about the range of topics that have to be considered. This could emerge as an issue for small and medium enterprises (SME) especially, due to limited resources and the challenge to fully grasp every aspect of Industrie 4.0 (Brettel et al. 2014, p.39). Therefore, this thesis aims to structure the aspects of Industrie 4.0 and provide assistance for the implementation of Industrie 4.0 scenarios. Based on this objective, the following research question for this thesis is derived:

RQ: What elements influence the implementation of cyber-physical production systems?

The main purpose of this research is the development of a reference model that identifies the relevant aspects for the implementation of Industrie 4.0 scenarios. It aims to assist decision makers with providing a classification of the content as well as identifying the implementation stages for a class of problems. The structure of this thesis is shown in Figure 1. Follwing this introduction, chapter two highlights the theoretical background of Industrie 4.0 and related concepts. The characteristics of the research method (action design research) and the research output (reference model) are then described in chapter three. The main part of the thesis, chapters four and five, outline the design process for the research output and explain the content and purpose of the reference model and the five views on Industrie 4.0. In chapter six, the practical application of the research output is tested with the presentation of three theoretical case studies that cover a range of Industrie 4.0 aspects. Chapter seven discusses the results by comparing the reference model to the Industrial Internet Reference Architecture (IIRA) and the Reference Architecture

Model Industrie 4.0 (RAMI 4.0), similar reference architectures that were published during the course of the research process. The thesis ends with the reflection of the limitations in chapter eight and finally with a conclusion that summarizes the results and provides an outlook for future use and research.

Chapter 1	Introduction	
Chapter 2	Theoretical Background	
Chapter 3	Research Methods	
Chapter 4	Model Generation	
Chapter 5	Results	Reference Model
		5 Views on Industrie 4.0
Chapter 6	Case Studies	Assistance Systems
		Automated Decentralized Decisions
		Predictive Maintenance
Chapter 7	Discussion	
Chapter 8	Limitation	
Chapter 9	Conclusion	

Figure 1: Structure of the Thesis

9. Conclusion

Production currently faces a number of changes that influence all aspects of the business. It not only affects the manufacturing site of an organization but also the business strategy and models, sales strategy and human resources alongside many others. Presently, the customer needs are detached from solely having an affect on the product and thus the production system of the manufacturer. Every element of the business is part of a dynamic system that changes its structure to meet the requirements of the current market. The changes can be divided into global changes that are essential for the business success in an international competition and local changes that are specific to the location of the manufacturing facilities or the customer market. Using the example of Germany as a production location, the demographic change forces the companies to adjust the production design to meet the demands of aging employees. However, the global changes ensure the competitiveness of the worldwide market. Currently, the biggest change for all businesses, regardless of their location, is the connection of production systems and products via the Internet. The result is the creation of intelligent products that are able to communicate with their environment, make decentralized decisions and adapt to the needs of the customer.

In order to implement these changes, the companies need to incorporate new technologies that drive the production. The flexibility to produce individualized products at the costs of mass production is not possible with current production technology. This can only be achieved with highly flexible production systems that consist of reconfigurable workplaces, which are designed to adjust to individual product configurations. As a result, the production shifts from static to a dynamic system that is able to make optimized real-time decisions. However, the new efficiency does not only affect the production systems but especially the workers. The use of new technology in production does not aim to create an automated manufacturing system and replace the human-worker. Through the digital representation of every aspect in production, the worker gets access to a number of new assistance systems that are used to provide the necessary information and help with error avoidance and reduction.

Central institutions such as the Plattform Industrie 4.0 and the Industrial Internet Consortium are founded to conceptualize and further develop these new tendencies in current production. They gather the knowledge of leading industry companies and manufacturer associations to propose further steps and successfully channel the new opportunities. As described in chapter 7, the IIC and ZVEI both released reference architecture to assist with the understanding and further development of new technologies, summarized under the terms Industrial Internet (IIRA) and Industrie 4.0 (RAMI 4.0). The here developed reference model and the five views on Industrie 4.0 take a slightly different approach to the structure of relevant components in Industrie 4.0. They focus on providing guidance for decision makers for the implementation of a range of scenarios in an organizational setting. Although the research output needs to be validated in a practical context to test the relevance for the end user, the theoretical case studies in chapter 6 suggest the application of the models for future use. Practitioners will especially benefit from a combined use of the research output in this thesis and the existing reference architecture. The reference model and the five views on Industrie 4.0 structure the implementation to incorporate the scenario into the business strategy while reference architecture such as RAMI 4.0 or IIRA assist with the specific design of the technology. Both approaches will assist the decision makers as well as end users to transform their business to meet the market requirements and lead to sustainable success.