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The Impact of Industry 4.0 on Procurement and Supply Management: A Conceptual and Qualitative Analysis

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ABSTRACT : *The ongoing discussions about a „digital revolution" and "disruptive competitive advantages" have led to the creation of such a business vision as "Industry 4.0". Yet, the term and even more its actual impact on businesses is still unclear.This paper addresses this gap and explores more specifically, the consequences and potentials of Industry 4.0 for the procurement, supply and distribution management functions. A blend of literature-based deductions and results from a qualitative study are used to explore the phenomenon.The findings indicate that technologies of Industry 4.0 legitimate the next level of maturity in procurement (Procurement &Supply Management 4.0). Empirical findings support these conceptual considerations, revealing the ambitious expectations.The sample comprises seven industries and the employed method is qualitative (telephone and face-to-face interviews). The empirical findings are only a basis for further quantitative investigation , however, they support the necessity and existence of the maturity level. The findings also reveal skepticism due to high investment costs but also very high expectations. As recent studies about digitalization are rather rare in the context of single company functions, this research work contributes to the understanding of digitalization and supply management.*

Keywords : *Industry 4.0, Internet of Things, Industrial Internet, Supply Management 4.0, eProcurement, Digital Procurement*

I. Introduction

While the use of digital technology has undoubtedly impacted the life of most individuals in developed societies, the picture of how it impacts business today is still vague in many respects (Kane et al. 2015). The German government brought forward an initiative to describe the impact of digital technologies on industrial production called "Industry 4.0" (BMBF, 2015). The term describes" the forth industrial revolution, a new step of organization and management of whole supply chains over the life cycle of products." (Platform I4.0, 2015). The term became a striking brand and an often-cited buzzword in many practitioners´ publications, as a marketing slogan of companies or industry associations to describe the bundle of innovative technologies (Adolph, 2014; Sendler, 2013).

Besides its popularity, "Industry 4.0" is still completely unknown to many. Even for the ones having heard it, the actual content of the concept is largely vague. A recent survey of 1.393 persons in Germany revealed that 82% had not heard the term Industry 4.0 before and of the 18% with pre-knowledge of Industry 4.0 more than 33% see simply the internet and communication networks as the core of Industry 4.0 while 25% could not give any statement about the real content of Industry 4.0 (IfDAllensbach, 2015).

The existence of similar terms such as the "Internet of Things", "Industrial Internet", "Internet+" or related issues such as "Smart Factory" or "Human-Machine-Cooperation" surely did not facilitate finding a common understanding of what really constitutes the next level of industrial business in form of "Industry 4.0" (Wang et al., 2015). One could say that all terms try to describe how – not whether or not - new digital technologies and networks will change businesses.

Yet, still it is not definitely clear what their content is and how they interact with each other. Therefore the basis to explain business in the digital era is still weak and it is hard to further analyze the effects of Industry 4.0 on distinct company functions, such as procurement and supply management. This is even worse, as it is assumed that previous industrial revolutions had their main effect on the shop floor of production, e.g. steam engine and electricity, while Industry 4.0 supposedly affects also other departments (Schuh et al., 2014).

The academic discussion of "Industry 4.0", the analysis of its content and the description as well as explanation of the developments the term is supposed to name still have to be picked up. Until now, the topic of Industry 4.0 is an under-developed research field, although research in these areas has inclined (see a.o.Brettel et al., 2014; Lee et al., 2014; Schuh et al., 2014). To date however, findings are rather anecdotal, lacking a conceptual and even terminological foundation. In addition, often discrete new technologies and their impact on industrial business are individually discussed (e.g. the effects of 3D-printing as the main cause of an industrial revolution; Berman, 2012), while recently some publications relate and analyze several technologies or enablers to Industry 4.0 (Brettel et al., 2014; Lee et al., 2014). Overall, practice and researchers are still challenged to explore the

causes and effects of Industry 4.0 on production, industrial business models and specifically to distinct other business functions such as procurement and supply management.

On the other hand, there are still doubts on whether Industry 4.0 actually constitutes a new development or if it is just an imposed hype (Drath and Horch, 2014). For procurement, this for example means that for many, the delineation between "eProcurement" and a however vague "Procurement 4.0" or "Supply Management 4.0" is still unclear. As eProcurement describes the support and execution of the procurement function by electronic technology means (Ronchi et al., 2010), it is often unclear what the new impact of Industry 4.0 really could be. With the procurement function as the key interface to the supply network, as such it is of high importance of a network production in the digital era. Therefore, research on procurement should contribute to answer the question about the potential of Industry 4.0, its use, opportunities, risks and barriers (Henke and Schulte, 2015).

This is the basic motivation for this contribution: to explore the phenomenon of Industry 4.0 from a procurement perspective. The purpose is to analyze and clarify the understanding of Industry 4.0, to reveal its impact onto the procurement area, to develop an initial conceptual foundation for a "Procurement 4.0" and to explore how these ideas have already been adopted in to today's business practice. More focused, the following research problems and questions will be addressed:

What are conceptual characteristics of "Industry 4.0"?

How does "Industry 4.0" impact procurement and supply management?

In order to answer the research questions set out above, a blend of a deductive and explorative research approach was developed. Based on a review of existing contributions in the field of Industry 4.0, attributes describing Industry 4.0 are derived to develop a reliable conceptual foundation. These are then mirrored against existing literature on procurement in the digital era, eProcurement and Electronic Supply Management in general. As a result, initial hypotheses how Industry 4.0 impacts procurement are derived. An exploratory study brings in initial empirical results on the state-of-practice of "Procurement 4.0".

The structure of this paper is reflected in this approach. In upcoming chapter 2, a review of Industry 4.0 and the development of a conceptual definition for "Procurement 4.0" are performed. This is followed by the explorative study in Chapter 3. After a brief description of the methodology, key findings from the study will be presented and critically discussed. As a key result, foundational premises for Procurement 4.0 are formulated. The paper closes with a summary and outlook.

II. Industry 4.0: Content Analysis With A View On Procurement

Review of Industry 4.0

The term "Industry 4.0" was established ex-ante for an expected "fourth industrial revolution" and as a reminiscence of software versioning (Lasi et al., 2014). According to Lasi et al. (2014), Industry 4.0 stands for an advanced digitalization within industrial factories, in form of a combination of internet technologies with future-oriented technologies in the field of "smart" objects (machines and products). This enables and transforms industrial manufacturing systems in a way that products control their own manufacturing process. The high importance of digitalization and the internet is also reflected in the discussions about related concepts such as the "Internet of Things" or the "Industrial Internet". Besides the focus on digitalization, Industry 4.0 is expected to be initiated not by a single technology, but by the interaction of numbers of technological advances whose quantitative effects together create new ways of production (Schmidt et al., 2015).

Even though some authors elaborate on unrealistic expectations and overenthusiasm (Messe, 2013), the potential of Industry 4.0 is expressed in the forecast of fundamental effects on industrial production and significant changes in the supply chains, business models and business processes (Schmidt et al., 2015). The most striking improvements are identified in the areas of competitiveness, innovativeness, flexibility, individuality, and working conditions (PlatformI4.0, 2015).

Trying to initiate a structured review on the term, it becomes obvious that Industry 4.0 is a popular term, but still the academic knowledge base is rather limited. The discussion about Industry 4.0 has increased recently and is relatively broad in the media and the (practitioners) public (google.com hits), but search results in academic publication search engines are quite rare (Science Direct or EBSCO Business Source Premseeier; Appendix A for details). Among them, the majority analyzes Industry 4.0 from an information technology perspective (e.g. Posada et al., 2015), very few from other business functions' perspectives.

To ensure rigor and replicability of the review, it is necessary to develop a coherent understanding of Industry 4.0. For this purpose 10 scientific papers were included in a scoping study. These papers were selected due to the authors' judgement about their relevance to the topic "Industry 4.0 and the supply chain". The chosen sample was discussed with experts in the field and updated during this process (Appendix B). The scoping study was used to identify several different definitions on Industry 4.0 and related concepts (Table 1), but was also used to develop an understanding of the effects of Industry 4.0 on the procurement and supply management function (ArkseyArksey and O'Malley 2005).

As one can see in Table 1, all definitions of Industry 4.0 describe the concept from a superior and cooperation perspective ("re-organization", "superposition" etc.), while technology is often named ("Big data") but is only the basis and enabler. Other terms, such as "cyber-physical systems" or "smart products" seem to describe sub-systems of Industry 4.0 ("Industry 4.0 embeds smart products"; "Industry 4.0 merges cyber/digital and physical systems"). Only the definition of the smart factory from Radziwon et al. (2014) is as comprehensive as Industry 4.0, as it also refers to a dynamic organizational solution ("smartness comes from forming a dynamic organization"). On the other hand its scope is somehow limited to production facilities.

Table 1 : Definition of Industry 4.0 and related concepts

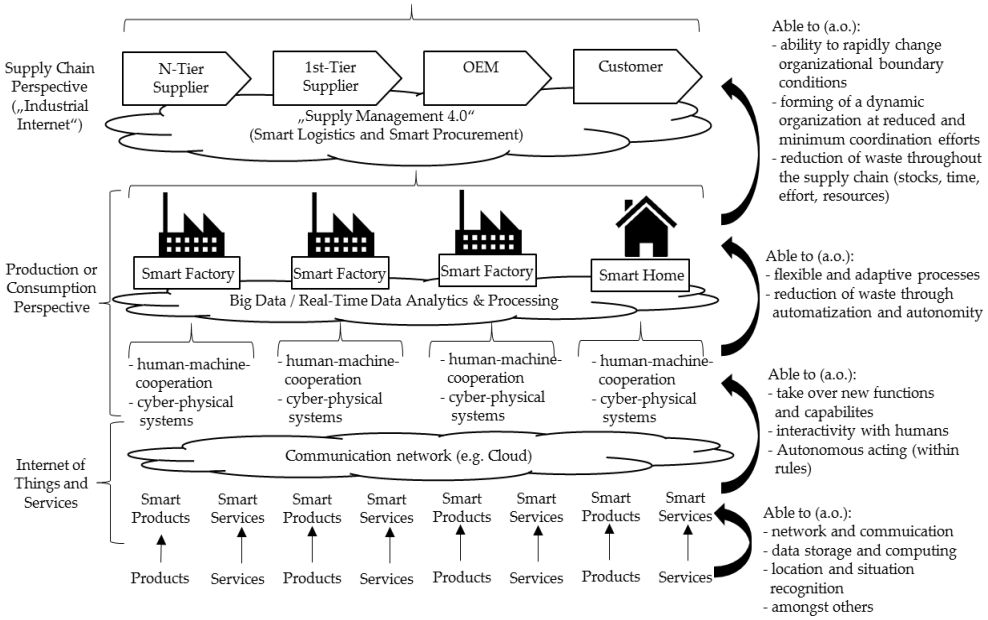
Term / concept	**Author**	**Definition**
Industry 4.0	Platform I4.0 (2015)	Industry 4.0 is a reform and re-organization of value chains to a networked coordination in the era of the 4th industrial revolution. More precise, Industry 4.0 uses real-time individual customer requests and environment balances ("Big Data") from all participant institutions of the value chain to holistically integrate the production process.
Industry 4.0	Schmidt et al. (2015)	Industry 4.0 is the superposition of several technological developments that embraces both products and processes. It is related to the so-called cyber physical systems that describe the merger of digital with physical workflow.
Industry 4.0	Sendler (2013), p. 7	Industry 4.0 is the linking of products and services with one another and with their respective environment through the internet and other network services that enables the development of new products of services so that many functions of products work autonomously – without human intervention.
Industry 4.0	Felser (2015	Industry 4.0 realizes an optimized collaborative value (smarter services and processes) by a smart cooperation of new and enhanced competences and capabilities in a supply network on basis of new technologies, in particular information and communication technologies.
Industry 4.0	Schmidt et al. (2015)	Industry 4.0 shall be defined as the embedding of smart products into digital and physical processes. Digital and physical processes interact with each other and cross geographical and organizational borders.
Cyber-physical system	Sendler (2013), p. 8	Cyber-physical systems is a network of interacting elements with physical in- and output in contrast to stand-alone machines but also in contrast to sole data or communication networks without physical in- and outputs.
Cyber-physical system	Schmidt et al. (2015)	Cyber physical systems include compute and storage capacity, mechanics and electronics, and are based on the Internet as a communication medium.
Internet of Things	Sendler (2013), p. 9	Internet of Things /Internet of Things & Services is describing a new evolutionary step of the Internet, as not only computers (including mobile terminal devices) are embedded in the network but any devices.
Internet of Things	Kovatsch et al. (2012)	Unlike traditional networked embedded systems, the Internet of Things interconnects heterogeneous devices from various manufacturers with diverse functionalities.
Smart Factory	Radziwon et al. (2014)	A Smart Factory is a manufacturing solution that provides such flexible and adaptive production processes that will solve problems arising on a production facility with dynamic and rapidly changing boundary conditions in a world of increasing complexity. This solution could be related to automation, understood as a combination of software, hardware and/or mechanics, […]. On the other hand, it could be seen in a perspective of collaboration between different industrial and nonindustrial partners, where the smartness comes from forming a dynamic organization.
Smart Products /Entities	Schmidt et al. (2015)	Smart products are products that are capable to do computations, store data, communicate and interact with their environment.

Therefore it is most important to state that Industry 4.0 is not limited to the technical dimension of digitalizing modern businesses (Felser, 2015), as it is rather the complete new organization and network coordination of value and supply chains (Platform I4.0, 2015). The authors of this article follow this far-reaching understanding of Industry 4.0, as this also makes clear that other concepts, e.g. "Smart Factory", "Internet of Things and Services" or "Cyber-Physical Systems", are sub-systems or sub-elements of the overarching Industry 4.0 concept (Figure 1 below).

As such Industry 4.0 can be understood following three key paradigms or perspectives (Felser, 2015; Schuh et al., 2014):Smart technical and engineering perspective: "Industry 4.0" is the usage of smart products and services within an appropriate technical environment (industrial internet of things; smart home; smart factory).Organizational and transformational perspective: "Industry 4.0" is the ability to dynamically create and rapidly use organizational interfaces for competence and capability networking.Economic, value-oriented perspective: "Industry 4.0" realizes collaboration productivity.

As such, "Procurement 4.0" or a "Supply Management 4.0" is a fundamental conceptual element of Industry 4.0 as it connects the different supply chain partners and enables a dynamic and rapid cooperation and coordination beyond organizational boundaries (Figure 1). In other words "without the procurement and supply chain management functions, Industry 4.0 is not to be successful in Germany" (Feldmann, 2015).

Figure 2 : The "Hierarchy" of Industry 4.0



Industry 4.0 and Electronic Procurement

One of the key paradigms of Industry 4.0 is the use of modern information technology (IT). However, this is nothing new in the context of procurement. Rather, the concept of electronic procurement (or "eProcurement") is well established (Brenner and Wenger, 2007a). It is therefore necessary to delineate the existing understanding of eProcurement from the implications of Industry 4.0 on procurement.

The application of IT in business organizations has developed since the 1970s, where the demand for production materials was structured using simple electronic system (known as "Material Requirements Planning", MRP). It was limited to connect internal departments such as production, material management and/ or procurement (Menges et al., 2014; Kuhn and Hellingrath, 2002). The functionality of these systems was similarly restricted.

The next stage of IT use in procurement was characterized by a stronger cross-company integration of IT systems, also known as "Enterprise Resource Planning" (ERP). Here, the use of the systems intended to provide a common basis for all major business functions across a company, spanning from sales over finance, again production (and others) to procurement (Saggau, 2007). The functionality still is focused on administrative and support of operative tasks.

While the step from MRP to ERP is rather evolutionary, the next development stage – eProcurement – could be called revolutionary. Flanked by trends such as eBusiness, Internet and Supply Chain Management, the technology use was bigger than ever (Kollmann, 2011; Essig and Arnold, 2001). Namely, this was the relatively easy integration of a company with suppliers (Essig, 2006). However, the term of eProcurement itself is not clearly defined. Some authors only see it as the support technology for operative procurement, with a distinct eSourcing for the tactical or strategic procurement tasks (Brenner and Wenger, 2007b; Stoll, 2007). The other, more comprehensive view is eProcurement as the general term for the use of IT in procurement. More concretely, the concept is defined as the use of Internet technology for facilitating operative procurement processes, such as ordering, as well as sourcing tasks, e. g. web-based supplier search or eAuctions (Koppelmann, 2007). From the technological perspective, the systems are used to facilitate tasks that previously

required heavy manual work (Wisner et al., 2015), e.g. the connection of suppliers with the ordering company by means of electronic data interchange (EDI) systems. Many studies show that eProcurement in general has been broadly adopted in organizations, as in specific instruments such as procure-to-pay operations (Bogaschewsky, 2015; McCue and Roman, 2012; Roland Berger 2011).

So if eProcurement is state-of-the-art, the question remains if and where implications from Industry 4.0 justify claiming a new development stage as in "Procurement 4.0". A review of the literature has found no dedicated research, apart from a few early works. Henke and Schulte (2015) for example claim that procurement at the interface of suppliers' technology and production technology holds the opportunity to position itself as the key driver of the Industry 4.0 development and postulate a number of questions around this. Other publications either have a mere technical focus (Sundermann, 2013) or focus on isolated aspects, such as logistical integration (Aslanbas, 2014). All in all, it can be said that there is currently no profound research on how Industry 4.0 impacts procurement.

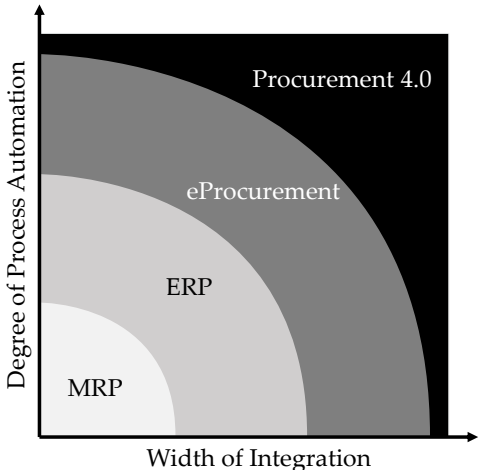
With a view on the paradigms of Industry 4.0 (see 2.1), one key aspect however seems to be the emphasis on "smart" IT systems (Schmidt et al., 2015). On contrary to the aspect of supporting manual work as in eProcurement (Wisner et al., 2015), it could be expected that smart stands for the idea of actual automation of entire procurement processes. Smart systems automatically recognize demand for a certain material and from that, independently generate an order that is transmitted to the respective supplier without any necessary human interference. The actual automation therefore can be seen as a distinction of "Procurement 4.0" versus eProcurement.

Another implication from Industry 4.0 on procurement IT systems can be derived from the organizational paradigm in Industry 4.0. While there has been a considerable advocacy for exchanging information and suppliers also in eProcurement (Kollmann, 2011), the technological advances alongside of Industry 4.0 have greatly increased the potential for doing this. The key change is the step from "exchanging information" to the "free flow of information" between connected products, services and consequently, organizations (Schlick et al., 2014; Wannenwetsch, 2005). The "exchange" commands some degree of activity by a buyer and a supplier, such as providing software interfaces or supplying actual data as a conscious act (van Weele, 2010). The "free flow" on the other hand implies a much higher degree of exchangeability of data itself, a higher degree of automation of the information exchange and possibly even the integrated use of the data under the concept of "big data analytics" (Lee et al., 2014).

Lastly, the productivity paradigm in terms of an enhanced "collaboration productivity" in Industry 4.0 (Schuh et al., 2014) is used to identify differences between Industry 4.0 and the existing approach of eProcurement. The productivity rent resulting from eProcurement initiatives is primarily caused by a reduction of transaction and process costs (Wagner / Essig, 2006). eProcurement transforms paper work into electronic software systems and then changes hitherto labor intense tasks to work-flow and IT supported processes. In the same way, eProcurement supports also strategic tasks, e.g. the supplier relationship management process (Essig, 2006). In extension of this, the key drivers of collaboration productivity of Industry 4.0 are enhancements in production and engineering. According to Schuh et al. (2014), Industry 4.0 enables radically short production development processes, enables new product-service functions and improves the organizational supply chain set up. Taken to extremes, eProcurement is focused on mere process-efficiency, while Industry 4.0´s goals are extended to increased productivity and performance to satisfy highly customized demands (Kagermann, 2014).

These implications can be used to distinguish eProcurement and Procurement 4.0. As carved out in describing the evolution of system use in procurement from MRP until today, it could be seen that the actual advancement happened in two dimensions: first, the degree of functional and cross-company integration and secondly, the degree to which systems reduced manual work in the procurement tasks, i. e. automation. Framing Procurement 4.0 with that, it becomes clear that both the depth of integration (especially across organizations) as well as the potential of autonomous automating entire procurement process clearly exceed that of eProcurement. The latter is limited to IT-based facilitation of tasks as well as customized information exchange. The following diagram displays this distinction, and extends similar "development curves" for IT use in procurement by the aspects of an independent Procurement 4.0 (Lawrenz et al., 2013; Wannenwetsch and Nikolai, 2004; Nekolar, 2003; Kuhn and Hellingrath, 2002).Consequently, actual process automation and the higher degree of integration constitute Procurement 4.0 and differentiate it from eProcurement. Procurement 4.0 stands for the ultimate digitalization and automation of the function within its company and supplier environment, but it is not limited to the use of new or enhanced technology systems. Alongside the degree of integration, supplier (chain) relationships will change as well in Procurement 4.0 (e.g. around new procurement objects, Wagner and Essig, 2006). As can be seen from these conclusions, the impact of Industry 4.0 on Procurement 4.0 is expected to be considerable.

Figure 2: The Evolution of Procurement IT Systems towards Procurement 4.0



III. Explorative Assessment Of Industry 4.0 In Procurememt

Interview Methodology and Sampling Characteristics

As indicated in section 1.2, a qualitative study is one basis of this contribution. Such an approach is especially appropriate for research problems where there is little to no prior knowledge (Voss et al., 2002; Brannick, 1997). As the conceptual review in chapter 2 demonstrated, this is the case for the Industry 4.0 topic. Since the goal of this paper is to shed light into a new topic, it serves an explorative purpose. As such, the collection of opinions, viewpoints and projections is the focus of data collection (Aghamanoukjan et al., 2009). Expert interviews are best suited to deliver this, yet given the maturity of the underlying research, the interview should be relatively open (Creswell, 2003). Semi-structured interviews along a conversation guideline were therefore applied (Appendix C). This is in line with previous research in the supply management field around largely unstructured topics.

The interviews were held with experts from companies in typical "Industry 4.0" industries such as capital equipment. A conscious selection of study participants is deemed appropriate for qualitative research, as it helps to produce more detailed insights (Dubois and Araujo, 2007; Patton, 2002; Eisenhardt, 1989). In total, seven interviews with a length of around 60 minutes were conducted (Table 2). Where possible, interviews were recorded and transcripted; in the other cases, extensive minutes were taken and confirmed with the participant afterwards (Yin, 2009).

Table 2 Overview of Interviews

Industry	Function	Source-Code
Train	Purchasing Manager Electronics	A
Machinery	Purchasing Manager	B
Education	Trainer/Lecturer Industry 4.0	C
Health Care Machinery	Purchasing Manager IT	D
Retail	Purchasing Manager	E
Machinery	Cost Engineering Manager	F
Insurance	Purchasing Manager	G

The collected data was analyzed using MAXQDA software that allows coding of the statements and deriving of recognizable patterns. Using software for qualitative research, specifically coding, has been widely applied in research (Corbin and Strauss, 2015). It not only allows an efficient data reduction, but also increases reliability. Overall, the code system included 13 different codes and 115 codings from the interviews. Those are the foundation of the observations concerning the practitioners' perspective on a "Procurement 4.0".

Key Findings

All interviewees see a high potential of Industry 4.0 which is estimated at minimum 7.5 up to 40 percent of total coordination and production costs (mean 21.25 percent). The interviewees expect savings in labor resources and a reduction of coordination effort across the supply chain, while product and process quality is at least stable or increasing (Interview A). Besides, it is expected to increase transparency, accountability, performance measurement and speed via Industry 4.0 (Interviews A and D). Overall, expectations are quite high, as Industry 4.0 shall achieve not less than to secure the economic future of the industrial base of Germany ("the country of

engineers") (Interviews A, B C and F). "Our company is in tight competition with companies with production sites in low-cost but near-shore countries such as Slovakia or Poland. Our company lost significant business and market share to these competitors. Industry 4.0 must provide a way out of this trap." (Interview A)
However, the time to realize and implement the vision of Industry 4.0 is expected to be very long. At minimum 4 years are mentioned to prepare the company for Industry 4.0 while several participants expect a decade to go before having Industry 4.0 realized (mean 6,92 years). On the other hand, all interviewees mention that the procurement function had not dealt with the developments of Industry 4.0 at all, respectively is not engaged in the company's efforts to achieve benefits from Industry 4.0. They heard the term from media or associations, and two interviewees mention efforts on new procurement processes together with improved eProcurement tools (Interview B and D). A "Procurement and Supply Management 4.0 – Strategy" or something similar could not be found in the interview cases.
One cause for this reluctance might be the puzzled understanding of Industry 4.0. Most procurement executives, except interview E, mention "buzzword", "marketing term" or other descriptions when talking about Industry 4.0. One even expresses his expectation that the term "Industry 4.0" will be forgotten in 5 years (Interview B). On the other hand all participants express the high relevance of the topic and the digitalization and (autonomous) cooperation as core content of Industry 4.0 (see Table 3).

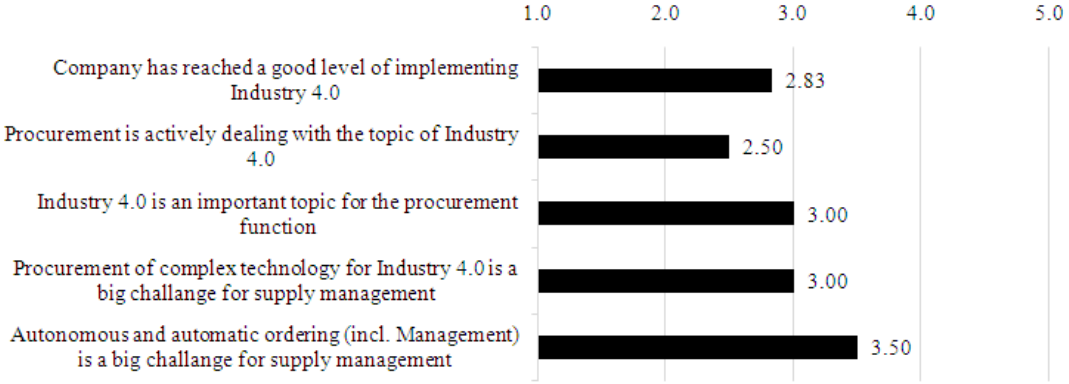
Table 3 Understanding of Industry 4.0 from the Interviewees

Source	**Statement**
A	"Industry 4.0 is a smart network, it is based technically on the Internet and all other means of network communication. It is a change from manual coordination towards autonomous coordination of learning systems."
A	"It is the vision to secure the competitiveness of the German Industry."
B	"It is the German term for the manufacturing future. It is very hard to understand the content of it, so it is a buzzword and forgot in 5 years."
B	„It stands for 100% more digitalization, automatization and network coordination."
C	„Industry 4.0 is a made-up and buzzword. It is all about Marketing, as it should be the new brand name for the German industry – similar to the success of "Made in Germany". It is a hype and there is a lot of "BlaBla" about it. I don´t see a revolution like steam engine was for industrial revolution."
C	"The content of Industry 4.0 are embedded systems and cloud computing what has effects on the whole supply chain. The improved capability of information and data processing, internet of things and the networks of data, e.g. SmartHomes, provides interfaces which are not bound to computers. Investment goods themselves are able to communicate over their life cycle."
D	"It is an umbrella term for several issues related with a modern value chain, but it its still only an idea with good approaches but the implementation is far behind vision."
D	"Big data management and the use of cyber-physical systems are the consequence of Industry 4.0".
E	"Industry 4.0 describes the integration of digitalization in hitherto traditional industries."
F	"Industry 4.0 is the digitalization of the whole economy including all crazy innovative things such as learning and autonomous systems, digital services, 3D printing and so on. The basis are high-performance computers."
G	"It [Industry 4.0] is the full digitalization of the supply chain, where the digital system is not supporting the supply chain managers but supply chain managers are supporting the system to automatically perform."

Despite the mixed picture regarding Industry 4.0, the interviewees see a lot of potential of it for the procurement function. "Increased transparency provides access to new suppliers" (Interview A). "Perfect and up-to-date data enables to optimize stocks and ordering schedules" (Interview B). "Manual ordering could be reduced to automatic and partly autonomous ordering (Interview C). However, all participants mention numerous and heterogeneous challenges of implementing Industry 4.0. The following are named and expressed: "Data security", "Data Ownership", "Binding Industry Standards", Open Access Standards", "Change and Knowledge Management of the Procurement Staff", "Lack of Best Practice Example", "High Investment costs", "Isolated Applications of parts of Industry 4.0", etc. In the interviews it became clear, that most problems are not only "procurement" problems, but more or less IT or general change management challenges.
In the questionnaire, there was also one question to evaluate the degree of Industry 4.0 implementation. As it can be seen in Figure 3, the (non-representative) sample shows that procurement could deal more actively with the topic. In the questionnaire, it was also explored which area the participant professionals notice as more challenging: the procurement of more complex and expensive technical equipment ("investment goods") vs. the implementation and controlling of an autonomous /automatic ordering system ("order processing"). Obviously,

the latter poses currently the most relevant challenges for the professionals, far more than the acquisition of modern technology ("smart equipment"). Another explanation could be that the procurement function is still struggling with the implementation of eProcurement-Software (Interview A, C, D). This will be discussed in the next section.

Figure 3 Indicative Results from the Interviews



In consideration of these challenges, the interviewees expressed the following capabilities required: "The future procurement professional is not expected to know more about IT" (Interview A). "Big Data Analytics is not the business of procurement personnel in the future" (Interview B). Overall the interviewees expect that procurement becomes a more technical function, but complexity and the difficulty in respect to IT know-how should be the same as today. Special capabilities, such as Big Data Analytics is expected to be performed in an extra department as a service for the procurement function. Surprisingly, the practitioners did not claim for more IT know how, rather they mention that the future procurement professional will develop towards a procurement manager with tasks of coordinating categories and to develop enhanced supplier and supply strategies. "We need personnel which is far more interdisciplinary than today. Besides IT this means also more expertise from production and logistics, but also economic and management know-how. The decisions taken should reflect a total cost perspective of the supply chain over the life cycle of products and equipment" (Interview C).

IV. Observations And Discussion

The findings from the interviews are now merged with the findings from the scoping study and the review. These are formulated in form of six observations (Obs 1 – Obs 6) and can be understood as initial hypothesis about the phenomenon of Procurement 4.0.

Obs 1. Technologies from Industry 4.0 enable the autonomous automating of entire procurement processes and the autonomous cooperation of goods and services across organizational borders. This clearly exceeds the content of the eProcurement approach and justifies distinguishing eProcurement from a new concept "Procurement 4.0" or "Supply Management 4.0" respectively.

Obs 2. Autonomous and automating processes across organizational borders in Industry 4.0 do not replace the procurement function. Rather, a Procurement 4.0 strategically assures the collaboration in a dynamic Industry 4.0 environment of rapidly changing organizational boundaries with appropriate contractual solutions and instruments for increasing the performance over the supply chain e.g. standardization.

Obs 3. Procurement 4.0 is not only focused on efficiency. Of course, coordination in Industry 4.0 shall be executed with a minimum of coordination costs and reduced waste. However, Procurement 4.0 contributes to the collaboration productivity aim of Industry 4.0 and improves the organizational supply chain set up to satisfy customized and innovative demands as efficient as possible.

Obs 4. Technologies of Industry 4.0, e.g. sensor technology, robotics, 3D printing etc., are expensive investments. These technologies are still being developed and have not yet met their peak of maturity. Therefore, Procurement 4.0 shall support the companies Industry 4.0 strategy with recommendations for integrating Industry 4.0 technologies available on supply markets.

Obs 5. The way towards a digitalized supply chain in Industry 4.0 cannot be stopped. However, Industry 4.0 bears numerous risks and challenges, namely the topic of data transparency, ownership and security. Procurement 4.0 can support with an appropriate risk and contract management other functions of the company to safeguard company's rights within Industry 4.0.

Obs 6. Doing business in Industry 4.0 requires numerous skills and capabilities across the company, e.g. Big Data Analytics. The capabilities required in the Procurement 4.0 function will change but must not include

necessarily extreme IT know how, as it is expected that software solutions become easier to use and complex tasks could be performed as a service for the Procurement 4.0 function.

Even if there is still a lot of skepticism in practice, Industry 4.0 is expected to form in its ultimate shape new digitalized supply chains, which shall realize collaborative productivity rents and ensure no less than the competitiveness of entire industries. Yet a smooth flow of goods and services including its efficient coordination requires a high degree of compatibility, modularity, universality, mobility and scalability in an Industry 4.0 supply chain (ten Hompel and Henke, 2014). This is not new, as these requirements have been requested already under the term of a "fractal factory" or the "borderless company" (Warneke, 1996; Picot et al., 2001). Similar to Warneke´s (1996) postulation to connect the different "fractals" (autonomous sub-elements within closed-loop control circuits), Procurement 4.0 must assure the contractual basis of the cooperation within Industry 4.0. Even if the theoretical discussion of the fractal factory or the borderless company could only be briefly touched in this contribution, these theoretical and conceptual references also support the above observed developments. 15-20 years after these publications, appropriate technologies seem to be available to establish enhanced support functions for autonomous production systems across organizational borders.

V. Conclusion and Outlook

In this work on Industry 4.0 two methodological approaches have been used to explore the impact on the procurement function. A scoping study was used to better understand Industry 4.0 while in-depth explorative interviews with seven procurement managers should reveal insights from practice. Of course this study is limited with regards to the number of participants in the explorative survey. However, the conceptual findings and empirical insights support the conceptual differentiation of "Procurement 4.0" from previous maturity levels of technology use in procurement.

The observations have been collected in form of six fundamental observations. Obviously, Procurement 4.0 must support superior Industry 4.0 strategies of the company. In this role it shall assure the dynamic cooperation across organizations borders and the achievement of a collaboration productivity rent, while safeguarding the companies risk exposure within the Industry 4.0 supply chain. However, research on the topic is still in its infancy, while practice signaled a high demand for explanative knowledge. More conceptual and empirical work is needed to better understand the effects of Industry 4.0 on procurement in detail. With these considerations in mind, this work is an initial exploration of the phenomenon and further observations need to be taken.

References

[1]. Adolph, S., Tisch, M., and Metternich, J., Challenges and Approaches to Competency Development for Future Production,*Journal of International Scientific Publications - Educational Alternatives*, 12(8), 2014, 1001-1010.

[2]. Aghamanoukjan, A., Buber, R., and Meyer, M., Qualitative Interviews, in Buber, R. and Holzmüller, H. (Eds.), *Qualitative Marktforschung. Konzepte - Methoden – Analysen*, 2. Ed. (Gabler, Wiesbaden, 2009) 415–436.

[3]. Arksey, H. and O'Malley, L., Scoping Studies: Towards a Methodological Framework, *International Journal of Social Research Methodology*,8(1), 2005, 19-32.

[4]. Aslanbas, M., Emporias Survey Procurement 4.0: Significance and Future Challenges for the Logistical Integration of Suppliers, in Emporias Management Consulting (Ed.), *Quarterly 3/2014*, (Emporias, Munich, 2014), 10–14.

[5]. Berman, B., 3-D printing: The new industrial revolution, *Business horizons*, 55(2), 2012, 155-162.

[6]. BMBF (Bundesministerium für Bildung und Forschung), *Zukunftsprojekt Industrie 4.0*, available at: http://www.bmbf.de/de/9072.php (accessed 12 August 2015).

[7]. Bogaschewsky, R., *State of the Art und Trends im eProcurement*, Poc. 6th BME e-Lösungstage, 24 March, Düsseldorf, Germany, available at http://www.cfsm.de/fileadmin/Downloads/E-Procurement/e_ltage_2015.pdf (accessed 10 January 2015).

[8]. Brannick, T., An overview of the research process, in: Brannick, T. and Roche, W. K. (Eds.), B*usiness research methods: strategies, techniques and sources*, (Oak Tree Press, Dublin, 1997) 1–29.

[9]. Brenner, W. and Wenger, R. (Eds.), *Elektronische Beschaffung: Stand und Entwicklungstendenzen*, (Springer, Berlin, 2007a).

[10]. Brenner, W. and Wenger, R., Anforderungen an Electronic Sourcing Systeme, in: Brenner, W. and Wenger, R. (Eds.), *Elektronische Beschaffung: Stand und Entwicklungstendenzen*, (Springer, Berlin, 2007b) 1–22.

[11]. Brettel, M., Friederichsen, N., Keller, M., and Rosenberg, M., How virtualization, decentralization and network building change the manufacturing landscape: An Industry 4.0 Perspective, *International Journal of Science, Engineering and Technology*, 8(1), 2014, 37-44.

[12]. Corbin, J. and Strauss, A. C., *Basics of qualitative research: Grounded theory procedures and techniques*, 4th Ed., (Sage Publication, Newbury Park, CA, 2015).

[13]. Creswell, J. W., *Research design. Qualitative, quantitative, and mixed methods approaches*, 2nd. Ed., (Sage Publications, Thousand Oaks, 2003).

[14]. Drath, R., and Horch, A., Industrie 4.0: Hit or Hype?, *Industrial Electronics Magazine*, IEEE,8(2), 2014, 56-58.

[15]. Dubois, A. and Araujo, L., Case research in purchasing and supply management: Opportunities and challenges, *Journal of Purchasing and Supply Management*, 13(3), 2007, 170–181.

[16]. Eisenhardt, K. M., Building Theories From Case Study Research, *The Academy of Management Review*, 14(4), 1989, 532–550.

[17]. Essig, M., Electronic Procurement - Konzeption und Anwendung, in: J. Zentes (Ed.), *Handbuch Handel*, (Gabler, Wiesbaden, 2006) 735-758

[18]. Essig, M. and Arnold, U., Electronic Procurement in Supply Chain Management: An Information Economics-Based Analysis of Electronic Markets, *Journal of Supply Chain Management*, 37(4), 2001, 43–49.

[19]. Feldmann, C.,*Ohne den Einkauf findet Industrie 4.0 nicht statt*, available at http://www.bme.de/ohne-den-einkauf-findet-industrie-40-nicht-statt-969/ (accessed 25 August 2015.

[20]. IfDAllensbach, Sicherheitsreport 2015, Ergebnisse einer repräsentativen Bevölkerungsumfrage, available at http://www.telekom.com/medien/konzern/282198 (accessed 20 August 2015).
[21]. Henke, M. and Schulte, A.T.,Einkauf und die 4. Industrielle Revolution, *Beschaffung Aktuell*, 62(3), 2015,. 20-21.
[22]. Kagermann, H., Chancen von Industrie 4.0 nutzen, in Bauernhansl, T., Hompel, M. Ten, and Vogel-Heuser, B. (Eds.), *Industrie 4.0 in Produktion. Automatisierung und Logistik*, (Springer, Wiesbaden, 2014) 603-614.
[23]. Kane, G. C., Palmer, D., Phillips, A. N., and Kiron, D., Is your business ready for a digital future?,*MIT Sloan Management Review*, 56(4), 2015, 37-44.
[24]. Kollmann, T., *E-Business: Grundlagen elektronischer Geschäftsprozesse in der Net Economy*, (Gabler, Wiesbaden, 2011).
[25]. Koppelmann, U., Internet und Beschaffung, in: Brenner, W. and Wenger, R. (Eds.): *Elektronische Beschaffung: Stand und Entwicklungstendenzen*, (Springer, Berlin, 2007) 23–38.
[26]. Kovatsch, M., Mayer, S., and Ostermaier, B. (2012), Moving application logic from the firmware to the cloud: Towards the thin server architecture for the internet of things, Proc. Innovative Mobile and Internet Services and Ubiquitous Computing (IMIS), 2012 Sixth International Conference, IEEE, 751-756.
[27]. Kuhn, A. andHellingrath, B., *Supply Chain Management: Optimierte Zusammenarbeit in der Wertschöpfungskette*, (Springer, Berlin, 2002).
[28]. Lasi, H., Fettke, P., Kemper, H.-G., Feld, T., and Hoffmann, M., Industry 4.0, *Business & Information Systems Engineering*, 6(4), 2014, 239–242.
[29]. Lawrenz, O., Hildebrand, K., Nenninger, M., andHillek, T., *Supply Chain Management: Konzepte, Erfahrungsberichte und Strategien auf dem Weg zu digitalen Wertschöpfungsnetzen*, (Springer, Berlin, 2013).
[30]. Lee, J., Kao, H. A., and Yang, S., Service innovation and smart analytics for Industry 4.0 and big data environment, *Procedia CIRP*, 16, 2013, 3-8.
[31]. McCue, C. and Roman, A. V., E-Procurement: Myth or Reality, *Journal of Public Procurement*, 12(2), 2012, 221–248.
[32]. Menges, M., Roubanov, D., and Ernst, J., Produktionsplanung und -steuerung (PPS), in Eigner, M., Roubanov, D., andZafirov, R. (Eds.), *Modellbasierte virtuelle Produktentwicklung*, (Springer, Berlin, 2014) 301–326.
[33]. Messe, H.,*Industrie 4.0 muss sich erst beweisen*, available at http://www.handelsblatt.com/unternehmen/industrie/hannover-messe-industrie-4-0-muss-sich-erst-beweisen/8044930.html (accessed 25 August 2013).
[34]. Nekolar, A.-P , *e-Procurement: Euphorie und Realität,*(Springer, Berlin, 2013).
[35]. Patton, M. Q., *Qualitative research & evaluation methods*, 3. Ed., (Sage Publications, Thousand Oaks, 2002).
[36]. Picot, A., Reichwald, R., and Wigand, R.T., *Die grenzenlose Unternehmung: Information, Organisation und Managemen*t, 4. Ed., (Gabler, Wiesbaden, 2001).
[37]. Platform I4.0, *Von smarten Objekten und Maschinen*, available at http://www.plattform-i40.de/ (accessed 24 August 2015).
[38]. Posada, J., Toro, C., Barandiaran, I., Oyarzun, D., Stricker, D., Amicis, R. de, Pinto,E.B., Eisert, P., Döllner, J., and Vallarino, I. Jr., Visual Computing as a Key Enabling Technology for Industrie 4.0 and Industrial Internet, *IEEE Computer Graphics and Applications*, 35(2), 2015, 26–40.
[39]. Roland Berger, *Purchasing-Excellence-Studie*, (Roland Berger, Munich, 2011).
[40]. Ronchi, S., Brun, A., Golini, R., and Fan, X., What is the value of an IT e-procurement system?, *Journal of Purchasing and Supply Management*, 16(2), 2010, 131–140.
[41]. Saggau, B., *Organisation elektronischer Beschaffung. Entwurf eines transaktionskostentheoretischen Beschreibungs- und Erklärungsrahmens*, (Deutscher Universitäts-Verlag, Wiesbaden, 2007).
[42]. Sendler, U., Industrie 4.0: Beherrschung der industriellen Komplexität mit SysLM (Systems Lifecycle Management), in Sendler U. (Ed.), *Industrie 4.0: Beherrschung der industriellen Komplexität mit SysLM*, (Springer-Vieweg, Berlin, Heidelberg, 2013), 1-20.
[43]. Schlick, J., Stephan, P., Loskyll, M., and Lappe, D., Industrie 4.0 in der praktischen Anwendung, in: Bauernhansl, T., Hompel, M. ten; and Vogel-Heuser, B. (Eds.), *Industrie 4.0 in Produktion, Automatisierung und Logistik: Anwendung - Technologien - Migration*, (Springer, Wiesbaden, 2014), 57–84.
[44]. Schmidt, R., Möhring, M., Härting, R. –C, Reichstein, C., Neumaier, P., and Jozinovic, P., Industry 4.0: Potentials for Creating Smart Products: Empirical Research Results, in: Abramowicz, W. (Ed.), *Business Information Systems*,(Springer, Cham, 2015), 16–27.
[45]. Schuh, G., Potente, T., Wesch-Potente, C., Weber, A. R., and Prote, J. P. (2014), Collaboration Mechanisms to increase Productivity in the Context of Industrie 4.0, Proc. 19thRobust Manufacturing Conference, CIRP, Bremen Germany, 2014, 51-56.
[46]. Sundermann, F., Einkauf 4.0: Einsparungen durch Zusammenarbeit von Einkauf und Technik, *Pool4Tool*, (11), 2013, 24-28.
[47]. TenHompel, M. and Henke, M., Logistik 4.0, in Bauernhansl, T., Hompel, M. Ten, and Vogel-Heuser, B. (Eds.), *Industrie 4.0 in Produktion. Automatisierung und Logistik*, (Springer, Wiesbaden, 2014), 615-624.
[48]. vanWeele, A. J., *Purchasing & supply chain management. Analysis, strategy, planning and practice*, 5. Ed. (Cengage, Andover, 2010).
[49]. Voss, C., Tsikriktis, N., and Frohlich, M., Case research in operations management, *International Journal of Operations & Production Management*, 22 (2), 2002, 195–219.
[50]. Wang, S., Wan, J., Li, D., and Zhang, C., Implementing Smart Factory of Industrie 4.0: An Outlook, *International Journal of Distributed Sensor Networks*, ePublication, Article ID 681806, 2015.
[51]. Wannenwetsch, H., *Vernetztes Supply Chain Management: SCM-Integration über die gesamte Wertschöpfungskette* (Springer, Berlin, 2005).
[52]. Wannenwetsch, H. and Nicolai, S., *eSupply-Chain-Management: Grundlagen, Strategien, Praxisanwendungen* (Gabler, Wiesbaden, 2004).
[53]. Warnecke, H.-J., *Die Fraktale Fabrik* (Rowohlt, Hamburg, 1996).
[54]. Wisner, J. D., Tan, K. –C, Leong, G. K., *Principles of Supply Chain Management: A Balanced Approach* (Cengage, Boston, 2015).
[55]. Yin, R. K., *Case study research: Design and methods*, 4th Ed (Sage Publications, Thousand Oaks, 2009).

Appendix A. Search string results

Search String	Google	Google Scholar	Science Direct	Springer Link	Business Source Premier (academic papers only)	Infoguide Bundeswehr University Search Engine
Industry 4.0	436.000	1.230	88	164	2	0
Smart Factory	267.000	1.030	79	227	3	2
Industrial Internet	608.000	1.240	45	65	13	92
Cyber-Physical System	86.700	4.950	895	1.811	29	6
E-Procurement	3.200.000	23.900	827	2.004	458	10
Internet of Things	217.000.000	59.100	1.924	5.014	332	23
Compared to						
Supply Chain Management	251.000.000	367.000	112.887	34.947	11.160	556

Appendix B. Publications of the scoping study

Author(s)	Year	Title and publication details
Bauernhansl, T., Hompel, M. Ten, & Vogel-Heuser, B.	2014	Industrie 4.0 in Produktion. Automatisierung und Logistik. Wiesbaden, Springer.
Blecker, T., & Graf, G.	2003	Internet based Production Concepts–Implications for Business Management. Proc. of 1st International Confernce on Business Economics, Management and Marketing, thens Greece, 26-29 June 2003.
Brettel, M., Friederichsen, N., Keller, M., & Rosenberg, M.	2014	How virtualization, decentralization and network building change the manufacturing landscape: An Industry 4.0 Perspective. International Journal of Science, Engineering and Technology 8 (1), 37, 44.
Hirsch-Kreinsen, H., & Weyer, J.	2014	Wandel von Produktionsarbeit–„Industrie 4.0 “. Soziologisches Arbeitspapier, 38.
Kersten, W., Schröder, M, Indorf, M.	2015	Industrie 4.0: Auswirkungen auf das Supply Chain Risikomanagement. In H. Koller, W. Kersten, & H. Lödding (Eds.), Industrie 4.0 Wie intelligente Vernetzung und kognitive Systeme unsere Arbeit verändern (pp. 101–126). Berlin: Gito.
Kirsch, A., Kletti, J., Meuser, D., & Felser, W. (Hrsg.)	2015	Industrie 4.0 Kompakt: Systeme für die kollaborative Produktion im Netzwerk. Competence Book.
Lasi, H., Fettke, P., Kemper, H.-G., Feld, T., & Hoffmann, M.	2014	Industry 4.0. Business & Information Systems Engineering, 6(4), 239–242.
Pfrommer, J., Schleipen, M., Usländer, T., Epple, U., &Heidel, R.	2014	Begrifflichkeiten um Industrie 4.0 – Ordnung im Sprachwirrwarr. Konferenzbeitrag auf der Entwurf komplexer Automatisierungssysteme, EKA 2014 (pp. 1–8). Magdeburg.
Schmidt, R., Möhring, M., Härting, R.-C., Reichstein, C., Neumaier, P., &Jozinovic, P.	2015	Industry 4.0 Potentials for Creating Smart Products: Empirical Research Results. Business Information Systems, 18th International BIS Conference. Posen, Poland.
Schuh, G., Potente, T.,Wesch-Potente, C., Weber, A. R., &Prote, J.-P.	2014	Collaboration Mechanisms to Increase Productivity in the Context of Industrie 4.0. Procedia CIRP, 19(RoMaC), 51–56.

Appendix C. Interview Questionnaire

Salutation and notes of data security and anonymity.

1. Position and Tasks in the Procurement Department of the Company
2. What is your understanding of "Industry 4.0"?
3. Which goals is "Industry 4.0" aiming at?
4. What is the potential of "Industry 4.0"? (e.g. Savings; Efficiency)
5. What are the most important challenges of "Industry 4.0"?
6. Is your company currently involved to implement "Industry 4.0"?
7. How did you get in touch with the topic "Industry 4.0"?
8. Is the procurement department already dealing with "Industry 4.0"?
9. What is your estimation about the potential of "Industry 4.0" in the procurement function?
10. What are the similarities and differences of "Industry 4.0" considering e.g. eProcurement?
11. How will "Industry 4.0" change the procurement tasks and processes?
12. Which capabilities is required in the procurement function in case of a realization of "Industry 4.0"?
13. How long does it take to implement "Industry 4.0" in your company /in your department?
14. Are your suppliers already dealing with the topic of "Industry 4.0"?
15. Please give us your opinion about the following statements:

	Scale from 1 = completely disagree to 5 = completely agree				
Our company has reached a good level of implementing Industry 4.0	O	O	O	O	O
Procurement is actively dealing with the topic of Industry 4.0	O	O	O	O	O
Industry 4.0 is an important topic for the procurement function.	O	O	O	O	O
Procurement of complex technology for Industry 4.0 is a big challenge for supply management.	O	O	O	O	O
Autonomous and automatic ordering (incl. its management) is a big challenge for supply management.	O	O	O	O	O