

# **Industry 4.0 and how purchasing can progress and benefit from the fourth industrial revolution**

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## *Abstract:*

Since its' announcement in 2011, the number of scientific publications on Industry 4.0 is growing exponentially. Significant investments by industrial firms, at present and planned for the coming years, indicate the expectations by the industry in terms of increased productivity because of the fourth industrial revolution. However, the link between purchasing and Industry 4.0 is largely lacking in scientific literature, despite the high financial impact of procurement for organizations. The fourth industrial revolution – cyber-physical systems with autonomous machine-to-machine communication – could enable several possibilities for purchasing. On the one hand support systems for purchasers are conceived, such as contract analysis software. On the other hand, the scenario of digital negotiations emerges, which could revitalize e-marketplaces. Operative processes can act autonomously, with automated demand identification in cyber-physical systems. In order to support the development of I4.0 strategies in purchasing, this paper further contributes by presenting the result of a project on developing a specific purchasing I4.0 maturity model.

*Keywords:* Purchasing; Supply Management; Industry 4.0; Smart Industry; Maturity profile; e-procurement; e-markets.

## **Introduction: Purchasing's central role in digital supply chains contrasting with a lack of specific research on I4.0's implications for purchasing**

Not long after its introduction, the steam engine became the symbol for the transition from manual to mechanical labor and thereby the key technology of the first industrial revolution. Since then, two industrial revolutions followed: mass production enabled by electric power and the industrial advancements enabled by information technology. Now, a fourth industrial revolution (Industry 4.0 or I4.0) is envisioned: the merging the physical and the digital world by means of cyber-physical systems and machine-to-machine communication.

The expectations of I4.0 are high, but purchasing's contribution to its realization remains unclear. For instance, recent studies of PricewaterhouseCoopers among German industrial firms show that in the next five years, companies will invest 3.3 percent of their annual turnover in Industry 4.0 applications (Koch, Kuge, Geissbauer, & Schrauf, 2014). In addition, the Boston Consulting Group, estimated an increase in productivity of five to eight percent by adopting I4.0 (Rüßmann et al., 2015) and the Fraunhofer society expects a cumulative added value potential of 23 percent between 2013 and 2025 (Bauer, Schlund, Marrenbach, & Ganschar, 2014).

Similarly to the industry, academia regards I4.0 as a key research topic. Since 2012, the number of publications on I4.0 has rapidly increased for each consecutive year. This quick rise appears to be partly attributable to the German Government, which adopted the name for their high-tech strategy 2020 for future projects (Lasi, Fettke, Kemper, Feld, & Hoffmann, 2014). A similar trend is observed for terms related to I4.0 (Smart Industry, Smart Manufacturing, Industrial Internet, Cyber-Physical Systems). The general question is, how firms can profit from I4.0? And how are supply chains changing in general and how could purchasing in practice contribute to seizing the chances the fourth industrial revolution is offering?

Surprisingly, while Industry 4.0 is flourishing in many streams of literature, research publications discussing I4.0's implications for purchasing seem to be largely absent from literature, as our extensive literature analysis has shown. This is a substantial gap in literature, since it is more than unlikely that the fourth industrial revolution has no influence on purchasing theory and practice. Hence, firms, researchers and educators benefit from discussing possible scenarios of I4.0 in purchasing.

The intention of this research is to provide insight in the fourth industrial revolution and the distinction towards the third industrial revolution, followed by exploration of the relevance of purchasing with I4.0 for academics as well as practical relevance for purchasing managers. This paper aims to contribute to current literature by means of a literature review, presentation of results from more than 15 recent workshops on I4.0 in purchasing, and a design project, which summarizes findings in form of an actionable purchasing I4.0 maturity model.

First, after briefly characterizing current I4.0 research, the three preceding industrial revolution are described, whereby the technical and organizational aspects are deliberated upon. Then, the distinctive characteristics of the fourth industrial revolution as compared to the third industrial revolution (digitalization) are explained. Next, the paper focuses specifically on purchasing with I4.0 and supporting applications. Thereafter, maturity models in general, ones tailored to I4.0 and our own proposed maturity model are outlined. Closing, an agenda for future research in purchasing and a conclusion are presented to summarize the findings of this study.

### **Literature on Industry 4.0: absence of purchasing**

Since 2015 publications on industry 4.0 and related topics have exponentially grown. To get a better understanding of the research fields that publish on the topic I4.0, we categorized publications on subject area. Table 1 makes a comparison between the subject areas of the documents found on Scopus for the four related topics. How publications are subdivided into subject areas indicates the relative importance of the subject areas for the respective topics. For clarity, the table is limited to only the top ten mentioned subject areas for I4.0. Thus, following the results in the table, publications from a business or management perspective typically connect to the term industry 4.0, compared to publications on Cyber-Physical Systems (CPS), which primarily refer to computer science.

Current frequently cited work in the field of Industry 4.0 is conducted by Kagermann et al (2013), Lee et al (2015), Lee et al. (2014), Monostori (2014), and Lasi (2014). In addition, Liao et al (2017) contributed the first published literature review on I4.0. Although the proportion of business literature on I4.0 is small, narrowed down to purchasing and I4.0, scientific literature is virtually inexistent. The query "purchasing" AND "industry 4.0" does currently not lead to any relevant results from academic search engines, and the query "purchasing 4.0" only mentions an exploratory case study classified as a master's thesis.

Table 1. Publications on Industry 4.0 and related topics in the last ten years by subject area (Reference date: January 30<sup>th</sup>, 2018; (percentages do not sum up to 100% due to overlap between subject areas)

Subject Area	Industry 4.0	Smart Industry	Smart Manufacturing	Industrial Internet	Cyber-Physical Systems
No. of publications	1958	69	480	596	7432
Engineering	65%	57%	59%	45%	74%
Computer Science	44%	56%	58%	75%	59%
Business, Management, and Accounting	16%	15%	8%	2%	8%
Decision Sciences	14%	8%	6%	4%	10%
Materials Science	12%	3%	5%	2%	8%
Mathematics	11%	8%	11%	19%	10%
Social Sciences	5%	8%	4%	4%	2%
Physics and Astronomy	5%	7%	7%	3%	3%
Chemistry	4%	-	3%	1%	2%
Energy	3%	3%	5%	3%	3%

According to the first literature review on I4.0 conducted by Liao et al. (2017) the enabling features of Industry 4.0 are the terms that most commonly appear in articles, e.g. Cyber-Physical Systems, Smart Factories, Industrial Revolutions, Internet of Things, Production Systems, Manufacturing Systems, Smart Manufacturing, Production Processes, and Cyber Physical Production Systems. In identifying the main research directions, the most-cited source at the time of writing (Kagermann et al., 2013) was referred to, which lists eight priority areas for actions. Before discussing the priority areas for action for purchasers, though, it is worth to clearly define I4.0 and distinguish the fourth from the preceding third industrial revolution.

#### **Four industrial revolutions: Technological drivers turned into revolution by organisational changes**

The industrial revolutions, so far, have been characterized a) by being ignited by new pacemaker technology, b) at first did only show slow productivity gains, which c) emerged only after reorganizing business. In the first revolution, the steam engine meant that one central power source became the center of one work environment – the first real factories emerging. The second industrial revolution is typically considered to have started in the 1860s with the advent of electricity and electrical motors. Having many decentralized power sources available, organizing production not following power transmission rules, but following a sequential logic of assembling a product became possible. The third industrial revolution, then, relied again on a new pacemaker technology, microprocessor enabled information technology, sometimes differentiated into computers and robots and called the “digital revolution” (Schuh, Potente, Varandani, Hausberg, & Fränken, 2014). Its start is typically terminated around the end of the 1960ies or the first oil price shock in 1974, which was a turning point in many aspects, for instance marking a shift in the spread of income (Greenwood, 1999; Jensen, 1993). An organizational consequence of digitalization was the reduction of variable costs. A globally

accessible computer program virtually does not cost any cent more, if one or one hundred persons use it. As a consequence of reduced variable costs, a winner-takes-all economy emerged (Brynjolfsson & McAfee, 2014).

Finding new organizational forms made possible by new pacemaker technologies is exactly the challenge firms face now, at the beginning of the fourth industrial revolution.

Table 2 Industrial revolutions and key technologies.

<b>Revolution</b>	<b>Pacemaker technology</b>	<b>Organizational transformation</b>
First	Steam power	From decentralized manufacturing to a centralized factory
Second	Electric power (engine)	From power transmission to assembly line production
Third	Microprocessor enabled digitalization (computer, robots)	From distributed production to winner-takes-all platform monopolies
Fourth	Sensor enabled cyber-physical systems and autonomous m2m communication	?

### **Anatomy of the fourth industrial revolution: connecting the physical world with cyberspace**

The question now is to identify the pacemaker technologies of I4.0, define industry 4.0 and, importantly, distinguish the fourth from the third revolution. A clear agreement on which would be the most important of these technologies lacks, though the literature analysis has shown that cyber-physical systems clearly get the most attention in publications. Also a widely accepted definition of I4.0 is still lacking in academia (Brettel, Friederichsen, Keller, & Rosenberg, 2014).

Several definitions for I4.0 have been proposed. Thoben et al. (2017, p. 5), for instance, define: “Industry 4.0 comprises a paradigm shift from automated manufacturing toward an intelligent manufacturing concept.” It remains unclear, though, what “intelligent” may comprise. Kiel et al. (2017, p. 673) define I4.0 as “a novel manufacturing paradigm ensuring flexibility and adaptability of production systems and value chains in order to maintain the future global competitiveness of manufacturing enterprises”. Here, a narrowing focus on manufacturing is given and also no clear distinction is made on what actually is ensuring flexibility; something, which has long been looked for. (Stork, 2015, p. 21) provides a detail in his attempt to define, I4.0, which in the context of purchasing studies is importance, by including the supply chain and suppliers: “The term Industry 4.0 [...] refers to the “fourth industrial revolution,” or the introduction of Internet technology in the manufacturing industry [...] and integrate customers more closely into the product definition stage as well as business partners into the value and logistic chains.” A problem with this definition, however, is the assumption of internet technology to be used, rather than other, more proprietary connectivity technologies. For data security reasons there are some serious doubts whether the relatively open internet would be the most feasible technological solution.

All in all, these definitions remain unclear in two aspects, namely in describing the constitutional elements of the fourth industrial revolution and in particular in clarifying how it differs from the previous, third industrial revolution of digitalization and automation. If the distinction between third and fourth revolution is not made clear, however, the danger remains that I3.0 applications are simply relabeled and no progress is made whatsoever. To differentiate between the industrial revolutions, we define I4.0 in the following way:

“Industry 4.0 is characterized by cyber-physical systems with autonomous machine-to-machine communication.”

This definition on the one hand is not narrowing down applications by pre-defining technologies (such as claiming that the internet would be the connecting technology or that it would only refer to manufacturing) and at the same time allows to very clearly distil the novel aspects of the development inducing the next industrial revolution. There are three key concepts, which can be applied as a check-list, assessing the completeness of a vision or of a solution provided, in terms of clarifying its progress from I3.0. In this way it becomes possible to accelerate technological progress:

(1.) Cyber-physical systems, explained as “transformative technologies for managing interconnected systems between its physical assets and computational capabilities” (J. Lee, B. Bagheri, & H. A. Kao, 2015, p. 21) stand at the core of I4.0. The particularly new feature is the connection between the physical and the digital world. The third industrial revolution introduced digital systems, which, however, did not by themselves connect to the physical world. In purchasing, the example at hand would be an electronic catalogue, which is a digital device requiring a human purchaser to enter his demand. In a cyber-physical system, on the other hand, the demand is detected by sensors, which observe that a material is running short.

(2.) Autonomy is the second of the constituting elements of I4.0 (Hwang, 2016), meaning that the system can “decide” for itself. Whether this decision is based on an pre-defined algorithms, expert systems or is based on artificial intelligence, it does not require further human intervention to function. An example would be smart machines, which can decide upon their own maintenance (Xu, 2017). In the third industrial revolution automated systems were installed. The difference to autonomous systems is that an automated system cannot react to novel situations, whereas an autonomous system reacts without external help. In purchasing, a simple application would be that a material decides on the moment of its replenishment. In an automated system (I3.0) the replenishment would work following a pre-defined plan, e.g. every first day of the month, whereas the autonomous system decides based on information it gets from the outside world when to replenish.

(3.) Machine-to-machine communication, finally, is another constitutional element, though a critical one as it requires safe communication to function (Sung, 2017). Instead of focusing on the human-machine interface, as in I3.0, now the novelty is that interconnected machines communicate with each other without requiring a human mediation. The classical case at hand are self-organized production environments, in which the machines communicate with each other and decide upon production, instead of leaving this activity to a central system. In purchasing, machine-to-machine communication would mean, for instance, that the computer of the buying firm orders material without an order from a human procurement agent.

One thing is worth to remark: While the origins of I4.0 lie in manufacturing, there is no reason as to why these principles should not apply to the entire supply chain (Tjahjono, Esplugues, Ares, & Pelaez, 2017). Therefore, it is worth (or even imperative) to explore in detail the potential implications of I4.0 also for the purchasing field.

### **The fourth industrial revolution in purchasing**

To systematically start a discussion on I4.0's impact on purchasing, it is helpful to first briefly summarize purchasing activities and then, in a second step, based on this sequence of activities, verify the impact of industry 4.0. Regular purchasing activities can be depicted in the “purchasing year cycle”. It can serve as basis for systematically assessing the I4.0 technologies' impact on purchasing.

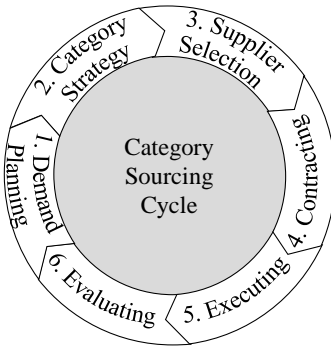


Figure 1: Purchasing year cycle

Based on corporate planning that reflects the firm strategy, purchasing plans the supply for materials and services and selects and contracts suppliers (strategic sourcing; steps 1-4 in the category sourcing cycle depicted in Figure 1). Subsequently, these plans are executed (operative procurement step 5), and their performance is evaluated (step 6).

#### *I4.0 applications supporting the purchasing year cycle*

Implementations of I4.0 must satisfy three practical characteristics (Kagermann et al., 2013). First, horizontal integration, that is, the aggregation of distinct supportive IT systems through value networks, for instance the inclusion of suppliers of raw material or manufacturers. Second, vertical integration, meaning the integration of support IT systems used at different hierarchical levels (e.g. the sharing of data and acting upon this information during the successive stages of the manufacturing process). Third, End-to-End digital integration, the overarching aim of both horizontal and vertical integration. This refers to the integration of all functions across the entire value chain, from product design and development to production and services. End-to-end digital integration is regarded as the most difficult aspect to achieve, since it encompasses collaboration by mutually sharing digital information within and outside the firm (Kagermann et al., 2013). Concerning I4.0 implementations in purchasing and reflecting the above distinction of purchasing activities, the following paths can be suggested:

- (1.) *Demand identification and planning*: Here, I4.0 technologies are not expected to show a big impact on the medium term, because the demand planning is mainly a company internal affair requiring data access on past demands, which is technically possible already by now. Next, it requires accurate sales planning, for which no I4.0 technologies have been presented, yet. One possibility, though, could rely in the use of big data analysis and artificial intelligence to improve or complement sales prognoses or to anticipate operative planning decisions (Dutta & Bose, 2015; Hofmann, Neukart, & Bäck, 2017).
- (2.) *Category strategy*: Defining a category strategy follows the typical strategic management approach, requiring an internal and an external analysis. The external analysis in the case of a purchasing strategy refers to the supply market. Here, expectations are that artificial intelligence agents might be able to support supply market analysis. A data engine would collect information, while the AI would filter out those which are relevant and present them to the purchaser. The challenge lies in the learning process. How to define relevant news? And then, how to create sufficient cases so that the AI can be instructed to develop its capabilities of distinction?
- (3.) *Supplier identification and selection*: In this process step, substantial achievements could be expected, exploring the ability for sophisticated text mining or artificial intelligence for analyzing the data available on suppliers (Hofmann et al., 2017). In the preparation of an RfQ it would be helpful to know all parameters of past offers, which may contain similar

parts like required. Currently such systems fail because of challenges in data classification. If this can be automatized through text mining. This could bring a break through. Based on a better knowledge on past projects, the purchaser could create a superior RfQ. Typically, then, suppliers may need some clarifications on how to respond. Here, the hope is that interactive bots could manage to answer many questions. Once the requirements are clarified, then, a big challenge for the purchaser arises: to analyze the offers submitted. Considering that offers for industrial components can easily exceed 100 pages, it becomes clear that currently a pre-selection has to take place and only a selected small number of offers can thoroughly be analyzed. The more a text mining system and in a next step an artificial intelligence can help to analyze offers and pre-select them, the more offers can be collected and seriously be considered, creating competition.

- (4.) *Negotiation and contracting*: Cyber-negotiations would be a logical next step. In that case, the parties would instruct their negotiation-avatars, which would then – in thousands of iteration steps – realize the actual negotiation. At first, this process resembles an automated negotiation, as the electronic agents follow the pre-defined instructions (Cao, Luo, Luo, & Dai, 2015; Idrus, Mahmoud, Ahmad, Yahya, & Husen, 2017). There are two steps with this: at first instance, the involved parties could instruct their negotiation-avatars by establishing rules and giving clear instructions. In principle, then, pre-defined algorithms would optimize themselves. The advantage is at least fourfold: a) both, selling and buying firms have to very clearly define their expectations in order to fill in the instructions for the avatar. b) not only price becomes negotiable, but finally other criteria, which have traditionally been disregarded due to complexity, can be negotiated as well. Even fraud detection could be improved (Zhang & Liu, 2016). Different negotiation arenas can be optimized, e.g. price, diverse quality and delivery criteria, terms and conditions, liabilities etc., c) an optimum can be found, instead of just satisficing, d) there is much less danger to damage the relationship as consequence of the hard negotiations. A special challenge to be overcome here is of legal nature. For instance, who should own the data generated?
- (5.) *Executing*: Cyber-physical systems could play a pivotal role in the execution phase, automatizing the demand generation in e-procurement systems, which are widely spread (Zunk, Marchner, Uitz, Lerch, & Schiele, 2014). Here, the connection between the physical world and the digital world needs to be added, for instance through devices like smart bins or sensor driven shelves, which recognize the depletion of a store of physical objects. In the execution phase, though of completely different nature, risk management support by artificial intelligence-driven systems. Similar to the expectation towards market analysis, a risk management system would identify and assess supply chain risks, relying on accessible data, for instance from internet resources. Another form of risk reduction could result from blockchain technology, which could find beneficial application in operative supply chains because of the creation of transparency (Tapscott & Tapscott, 2017). In case every legitimized member of a chain can access the chain data, potential delays or quality failures can already be detected early on and corrective action can be taken.
- (6.) *Supplier evaluation*: Finally, in supplier evaluation an old dream of automated data analysis for evaluation could come closer. On the other hand, a more limited change impact could be expected, because such systems do not rely only on data extracted from the ERP system, but require subjective evaluations from the interface partners (in industrial applications typically next to purchasing itself, quality, logistics and engineering). These, by their nature, cannot be taken over by digital systems.

Some of the above elements could be combined, such as automatic demand generation through cyber-physical systems and cyber-negotiations. This combination could revitalize the idea of electronic market places, which failed during the “dot.com-hype” in the early 2000s,

presumably because as long as there is a human-machine interface in the moment of entering the demand into the system, an electronic market place could not offer very much more than a more comfortable paper catalogue. If demand is generated automatically and a cyber-negotiation takes place – every pencil could be negotiated, if it is electronically – emarkets could gain a new role.

Taking the perspective of a firm, the question arises how to systematically assess its potential for profiting from industry 4.0. To make a proposal for this, it could be helpful to have a maturity model, which allows to define a target to achieve and develop a step-wise roadmap to reach that goal. In order to develop this, we started a research journey.

### **Operationalization: A maturity model for purchasing**

*Method: Design case, workshops and an extensive literature review*

The study originated from an aspiration to discover how purchasing can progress and benefit from the fourth industrial revolution. Several procedures were followed to ensure an academically sound prediction for the future of purchasing with I4.0. In the aim for both academic, and practical relevance, this research draws on four constructive elements: an extensive literature review; future directions for purchasing; 16 workshops on industry 4.0 application to purchasing; and a design case that integrated the preceding elements in form of a maturity model.

Starting, an exploratory approach was applied to familiarize with the topic I4.0. A systematic literature review was conducted, starting with terms including industry 4.0, smart industry, cyber-physical systems, and machine-to-machine communication. Hereby, results from Scopus were analyzed in depth to gain understanding of subject areas, geographical dispersion, frequently cited articles and authors, and the development of the number of annual results. This approach contributed to a fundament on which the design project built and contributed to the first attempt to sketch potential I4.0 applications in purchasing. The information required for this part was acquired from both academic literature as well as operational experience from the industry. Arising from the incentive to explore the future of purchasing, a total of 16 workshops on I4.0 targeted at purchasing managers were organized in Switzerland, Austria, France, Germany and Finland. Altogether more than 250 purchasers and purchasing managers attended these “fit for industry 4.0 in purchasing” workshops. Before the maturity model was constructed, alternative existing maturity models on I4.0 were analyzed and compared to identify their focus areas. The instrument was then evaluated by purchasing managers during the last two workshops. The feedback of the purchasing managers let us reconsider how advanced the first two stages of the maturity model should be.

*Eight layers of industry 4.0: strategy, process, physical, p2p, kpi, sourcing, suppliers and human readiness*

In developing a maturity model, a fundamental question refers to the question along which categories the maturity can be described. One approach could have been to pick the previously described purchasing year cycle and develop a scheme for each step. However, the problem with this is that often one implementation of an I4.0 tool would refer to several steps. Instead, it proved to be more operational to update a model originally conceived by Hazelaar (2016) who developed an I4.0 roadmap in indirect materials at a leading Dutch technology company. In the context of the development, Industry 4.0 relates to implementations of machines that make decisions autonomously, facilitated by data-driven machine-to-machine communication and cyber-physical systems that convert the analyzed and communicated information to action. Nowadays, digitization takes place in business processes throughout the entire value chain instead of the role of back-office support that information technology once had (El Sawy, Malhotra, Park, & Pavlou, 2010). Despite its increased role of importance however, knowledge



regarding their level of digitization is lacking within firms (Leyh, Bley, Schäffer, & Forstenhäusler, 2016). As stated earlier, maturity models are helpful tools for organizations to assess their current level of development, of in this case digitization. Moreover, a practice-oriented definition of I4.0 is desired to propel further digitization in alignment with the long-term vision and strategy of organizations (Lichtblau et al., 2015).

The result of the preliminary research is the design a maturity model of eight layers: (1) strategy, (2) process, (3) physical level, (4) purchase-to-pay, (5) purchasing controlling structures, (6) sourcing, (7) supplier involvement and (8) human readiness. Within the eight layers, each item for assessment is described for four maturity levels where level one describes a pre-mature stage of I4.0, by which a lack of adoption of I4.0 concepts is meant. Level four represents world-class performance, a profound adoption of I4.0 concepts fulfilling all three constitutional criteria defined above (cyber-physical, autonomous systems and machine-to-machine communication) and alignment of concepts on a strategic level of the organization. For a more detailed overview of the maturity model see the Appendix.

1. *Strategy*: Before firms can start adapting the fourth industrial revolution, a strategy is required to prioritize the focus areas of the organization before moving towards the future desired state (Geissbauer, Vedso, & Schrauf, 2016). For this reason, strategy is the first layer of our maturity model. A distinction is made between an I4.0 strategy, determining requirements and priorities for the entire firm, and ultimately an I4.0 strategy tailored to purchasing. The latter is an important refinement, because strategic purchasing positively effects the financial performance of the firm (Carr & Pearson, 2002). Firms, in first instance, have to ask, if they do have an I4.0 strategy in purchasing?
2. *Process and systems*: A model that describes how to overcome the challenges of I4.0 and how to reach organizational targets is incomplete without processes that arise from the adapted strategy. At the beginning of the previous decade, the expected potential of e-procurement systems rose due to technological progression and an increased role of importance for procurement (Presutti Jr, 2003). In line with the role of procurement shifting from reducing cost to creating value, modern e-procurement systems facilitate many operational tasks, among which reducing transaction costs and increasing contract compliance, thereby saving time for purchasing personnel to concentrate on strategic, value-creating tasks (Aberdeen Group, 2005). Industry 4.0 offers improved capabilities for gathering and sharing information in real-time, and thus new opportunities for further improvement of purchasing processes. I3.0 e-procurement processes, often catalogue based, are the basis for further development into I4.0 processes, by enhancing the machine-to-machine communication and changing the interfaces to cyber-physical systems. Hence, the fundamental question for firms is to ask if they have fully implemented I3.0 (software) systems and have extended them into the physical world and autonomous connectivity? A combination of process improvement and software implementation is discussed. The two things should not be separated into two different layers in order to offer the chance and better comply to the requirement discussed above, that a technological update should lead to an organizational change, in order to generate a productivity enhancing revolution. Else, the danger arises of running again into a technology adoption paradox like in the beginning of the 1990ies (Brynjolfsson, 1993).
3. *Physical level*: While Cyber-Physical Systems are inseparable from the fourth industrial revolution (Kagermann et al., 2013), existing maturity models only briefly mention CPS or omit the physical aspect entirely. Regarding I4.0 as a digitization solely thriving on IT-systems, Cloud, or Big Data would not do the fourth industrial revolution justice. Hence, the maturity model presented here includes a physical level. It is expected that a fusion of real and virtual systems is likely better suited to operational purchasing, for

instance through self-filling systems equipped with Machine-to-Machine communication functionality to order goods without human intervention (Fukui, 2016). In the third layer, hence, the main question firms may want to ask themselves is, where a connection to the physical world makes sense and how it is implemented? Please note that here a wide arrange of possibilities exist, starting with simple replenishment of small items in office and production, but also extending to such things as autonomous maintenance tasks.

4. *Purchase-to-pay*: Preventing or reducing, purchasing outside available contracts or ‘maverick buying’, is often mentioned as incentive for adopting e-procurement systems by firms (Angeles & Nath, 2007; De Boer, Harink, & Heijboer, 2002). The increased analytic and communicational capabilities associated with I4.0, such as Big Data analysis, are expected to progress contract compliance and increase automation of the payment process. The guiding question here is, in how far the P2P process of a firm is fully automatized and able to autonomously solve problems?
5. *Purchasing controlling structures*: Taking the right decisions is critical to stay in business in fast moving industries. With I4.0, end-to-end transparency of Key Performance Indicators in real-time becomes possible (Kagermann et al., 2013), which allows purchasing managers to intervene directly when needed. Hence due to its large impact on decisions, data should be carefully collected, stored, analyzed, shared and archived, and essentially treated as an asset by organizations (Wee, Kelly, Cattell, & Breunig, 2015). Nonetheless, the extended possibilities of retrieving and analyzing data also entail risks related to cyber security, for instance prevention of unauthorized access or modification of data. The question here is if the firm uses the I4.0 possibilities to collect and analyze purchasing data?
6. *Sourcing*: Data analysis based on data traffic from web shops is commonly used by companies to predict demand. For strategic purchasing, firms are expected to benefit more from data analyses when the results are shared within the organization via connected systems, this transition will require significant effort though (Geissbauer et al., 2016). Despite the expected increasing role of importance for data analytics, firms should aim for distilling useful information out of data to generate insights instead of generating as much data as possible (Lee, Lapira, Bagheri, & Kao, 2013). To provide guidance in beneficially using data for strategic purchasing, our model assesses sourcing by addressing predictive demand, market analysis, specification, and contracting including cyber-negotiations. Firms may want to assess and plan the applications of I4.0 technologies, mainly in data analysis, to support strategic sourcing?
7. *Supplier involvement*: To achieve horizontal integrated supply chains collaboration with suppliers is needed, so the willingness of suppliers to adopt I4.0 practices should be assessed in an early stage (Kagermann et al., 2013). A noticeable difference between the literature and experiences in practice is the desired level of supplier involvement. During discussions at several of our I4.0 workshop, purchasing managers indicated to be cautious about sharing data with supply chain partners. Conversely, literature deems collaborative networks essential to achieve I4.0 (Brettel et al., 2014; Geisberger & Broy, 2012). The fundamental question in this layer is if the suppliers of a firm – and in case: which – are ready to collaborate with the focal firm, as some I4.0 installations may incur substantial costs and increase competition?
8. *Human readiness*: The final layer of the model measures whether employees are ready for adopting I4.0. Other models support the importance of training personnel to achieve the necessary skill set (Geissbauer et al., 2016; Jodlbauer & Schagerl, 2016; Lichtblau et al., 2015; Schumacher, Erol, & Sihm, 2016). In our model a distinction is made between the expected required capabilities for employees and the degree of involvement

of employees during the change process. Here, the question is how have the employees in purchasing been prepared and trained to use the new technologies?

Based on these eight layers a systematic managerial and academic discussion can be started.

### **Conclusion: Contributions and a research agenda for purchasing to coin the ongoing industrial revolution**

In this paper, we have analyzed the potential impact of the fourth industrial revolution on purchasing and developed a maturity profile which can serve for firms to develop an I4.0 strategy. By doing so, this paper contributes at least fivefold:

- (1) The Literature, so far, has largely ignored purchasing as an object or subject of the fourth industrial revolution. This paper contributes with a first attempt to systematically analyze potential chances and challenges and integrate purchasing and supply management into the discourse on I4.0.
- (2) In terms of managerial contribution, here, an actionable tool is proposed, the maturity model. In this way, practitioners – but also academics – can structure their approach to seizing and understanding the I4.0 implications for purchasing.
- (3) Exceeding the purchasing domain, this paper contributes by providing a systematic and actionable definition of industry 4.0, whose three constitutional elements – cyber-physical, autonomous and machine-to-machine communication – can be used to check if a potential application is really an I4.0 application and likewise can serve as guideline to develop such applications.
- (4) An obstacle to the progress of I4.0 can be seen in the lack of a clear differentiation towards digitalization, the third industrial revolution. Often, “old wine is served in new bottles”. This paper contributes with a clear differentiation between I3.0 and I4.0, which clarifies definitions and thus enables research progress.
- (5) Finally, providing a solid embedding in the history of the industrial revolutions, this paper contributes by pointing to the need to not only implement new technologies in existing processes, but to change these processes in order to achieve productivity increase. With this reminder, we hope to be able to contribute to shorten the unproductive investment paradox phase which was typical for the beginning of each industrial revolution.

If the decision to term the recent development as “industry 4.0” and hence embed it into the tradition of industrial revolutions had not effectively already happened, this paper would have made another point to the use of this term, as the historical review makes the concept much richer than competing terms, which are much more difficult to define and to turn actionable.

However, this study has also shown that research on I4.0 in general and I4.0 in purchasing in particular is still at its infancy. Before the fourth industrial revolution really reaches its productive phase, many pieces of research remain to be done, in particular (1.) concerning the operationalization of the eight layers developed for the maturity model, (2.) the stepwise analysis of the I4.0 technologies and their applicability for purchasing, (3.) the impact I4.0 has on the skills needed for the purchaser of the future and finally, (4.) strategic implications and possible business model changes induced.

- (1) Concerning the need of research on the eight layers, in terms of purchase-to-pay process the operationalization and assessment of automated demand generation through cyber-physical systems strikes out. In combination with cyber-negotiations this feature could lead to a re-vitalization of the idea of electronic market places, which would be a fruitful path for future research. What also becomes clear in the context of autonomous

negotiations, is that we need much a better understanding on negotiation theory and empirics, which has been neglected in the past.

- (2) Looking at the pacemaker technologies of I4.0 and their impact on supply management, the blockchain technology would need to be better understood, as it has the potential to create the transparency in the supply chain purchasers have been dreaming of since long. Transaction costs would decrease, trade without trust could become possible and hence a profound transformation of purchasing could take place. Likewise, the application of artificial intelligence, for instance as a source providing purchasers with a series of supporting tools, like in supply risk analysis or market analysis would be an important field in need for more research. Finally, the emerging digital twin technology could have as a consequence that a product is not sold once and then disappears from sight of the producer, but could stay connected through its entire life-cycle. In that case, new contracts would have to be made, for instance covering the liability issues resulting from a life-long perspective. Purchasing needs to adopt to this novel sourcing situations, for which further research could be very fruitful. Green procurement and credal to credal concepts can get re-vitalized.
- (3) All of this is unlikely to leave the role model and hence the skills requirements of purchasers untouched. Here, a strong need for further research emerges: which are the competences needed and how to manage the change process towards a new role? If digital and autonomous negotiations establish, the task of purchasers would move out of a direct face-to-face negotiation focus, to more a thorough and cross-functional preparation of tenders and negotiation focus. Competition would increase, then calling for a better understanding of buyer-supplier relations in order to take suppliers with.
- (4) All of these changes may have strategic implications. Fruitful research with a purchasing core would have to analyze I4.0's implication for supply chain configuration and business models. Are traditionally closed supply chains disintegrating and electronic market places with constantly changing partners taking over or would, instead, even closer supply chains develop with costly software integration?

Finally, some limitations of this study and its conclusions have to be acknowledged. The novel nature of I4.0 makes it almost endemically vulnerable towards errors in judgement. For instance, the assumptions underlying the maturity model will have to be checked empirically in the time to come. The same refers to the question which technologies will actually prevail and coin the fourth industrial revolution. It could also be that our study has a bias, as most of the attendants to the many I4.0 workshops we conducted came exactly for being unsecure about the future. Maybe the more knowledgeable purchasers and their insights have thus escaped to our attention. Probably, still quite some case studies of I4.0 in purchasing have to be added, but eventually a quantification of findings needs to take place.

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