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Supply Chain Process Oriented Technology-Framework for Industry 4.0

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Digitalization in supply chains is an arising topic. Screening recent publications in this field delivers no application-oriented classification of potential Industry 4.0 technologies for supply chain processes. The purpose of this paper is to present an application-oriented Technology-Framework speeding up the development of digitalization scenarios for supply chain processes.A structured literature review will be carried out to identify and extract relevant technologies within the field of Industry 4.0. Afterwards, the Process Chain Model will be used to come up with standardized and application-oriented categories for technologies to derive a framework. Based on a comparative study, the Process Chain Model was especially developed for illustrating and transforming supply chain and logistics processes.The new Technology-Framework supports the transformation process by giving the user (1) a standardized framework for technology categorization and (2) by giving a comprehensive overview about existing technologies in the literature. The framework serves as a basis for future supply chain process transformation. By grouping the technologies around approved categories – originally defined for describing process chain elements – it speeds up the identification and selection of appropriate technologies.

Keywords: Industry 4.0; Supply Chain Management; Digitalization; Technology scouting

1 Introduction

Digitalization plays an important role in many sections of daily life. In the industrial environment, more and more companies are also pursuing measures to integrate technologies into business processes and thus to digitize their processes (Roth, 2016b). In the literature exist further terms with a similar meaning for digitalization (Hermann, Pentek and Otto, 2016). Especially the term of Industry 4.0 (I4.0) has determined both the economy and science for some years (Wan, Cai and Zhou, 2014). Background of the terminology is the increasing customer requirements for individualized products. The resulting smaller batch numbers down till batch size one and shorter product life cycles lead to steadily growing challenges not only for production and logistics, but throughout the entire supply chain (SC) (Bauernhansl, 2014). In order to counteract this increasing complexity and to meet the market requirements with regard to price, quality and time, companies are forced to increase their technological standard in their SC processes (Kersten, et al., 2016). Thereby I4.0 pledges improvement in flexibility, product quality, delivery time and deliverability in value-added networks (Bauernhansl, 2014).

The term of I4.0 is described by the use of existing technologies, such as microcomputers, broadband internet access, radio frequency identification (RFID), and stronger networking creating a comprehensive transparency and processing of information along the entire value chain (Siepmann, 2016a). Additionally, I4.0 is also to be seen as a new optimization approach, because a faster information flow results from a reduction in media discontinuities and a stronger technological and organizational process transparency. As a result, more tightly clocked process chains emerge (Schlick, et al., 2014).

Although the term of I4.0 has been in existence for several years, there is still no uniform definition (Siepmann, 2016b). For this paper, the holistic definition of Roth (2016b) will be used. He defines I4.0 as ”[...] the networking of all human and machine actors over the entire value chain as well as the digitalization and real-time evaluation of all relevant information with the aim of making the processes of value creation more transparent and efficient in order to use intelligent products and services to optimize customer use”.

The “Dortmund Management-Model for Industry 4.0” by Henke gives a further direction for practitioners and researchers with establishing and formalizing “work-clusters” in a two-dimensional matrix for transforming value creating activities (ten Hompel and Henke, 2017). The first dimension describes a company perspective with ”Technology”, ”Organization” and ”Process” as characteristics. The second dimension has a management perspective with ”normative Level”, ”Planning”, ”Implementation” and ”Monitoring” as characteristics. The following paper contributes to the work-cluster of ”Technology scouting” within the ”Technology” and ”Planning” dimensions.

In this context, science is discussing the extent to which a revolution can be addressed in I4.0. Accordingly to Dais (2014), there are two different groups regarding interpretation of the term. One group recognizes I4.0 as revolutionary as it brings innovative improvements with it that have not yet existed. The other group speaks of evolution, since the technologies are ”nothing new”, but constantly evolving and improving.

Despite this fact, I4.0 technologies can make a valuable contribution to the digitalization and autonomization of processes. However, not many efforts beyond I4.0 pilot projects are carried out in practice. Oftentimes, I4.0 technologies are implemented only partially in the logistics or production, so that the desired cost and benefit effect for companies does not occur (Graef, 2016). The reason for partial solutions is often insufficient knowledge about the correct use of the right technology for the respective process. Meanwhile, a large number of technological solutions exist to improve business processes (Kersten, et al., 2016) and a support is required to help companies in the correct use of I4.0 technologies in existing SC processes.

In recent literature, I4.0 technologies and fields, illustrated with mind maps and other classification methods, are known (Pfohl, Yahsi and Kurnaz, 2015; Kersten, et al., 2016). However, these classifications are not very suitable for practice. Also I4.0 technologies are described in use cases in which these technologies are often used only in production or logistics and not in the overall context of a SC (e.g. Zhang, et al., 2014). In addition, there is no framework in the literature that provides the technologies of I4.0 for the optimization of SCs. Therefore, the aim of this paper is to develop a Technology-Framework that provides methodological support for the optimization of SC processes. For this purpose, the following research questions (RQs) arise:

RQ 1: Which existing technologies in the literature relate to the context of I4.0 and how can they be classified for practical usage?

RQ 2: How can a relation between the identified technologies and classical process optimization methods be established?

In order to answer these RQs, the methodological approach will be explained in section 2. In section 3, the methodology will be executed and an overview of the existing literature in the research field will be provided. The development of the Technology-Framework by listing existing I4.0 technologies, establishing a relation between them and process optimization as well as integrating the results into the optimization framework will take place in section 4. In section 5, a conclusion and further needs for research follow.

2 Methodology

Today, the whole topic of I4.0 is still an emerging, under-developed and highly diverse research field (Pfohl, Yahsi and Kurnaz, 2015; Glas and Kleemann, 2016) and the application of more exploratory research methods is suitable to give first directions (Stebbins, 2001) instead of a final answer. Three principal ways of conducting exploratory research are mentioned in the literature (Saunders, Lewis and Thornhill, 2009): Search of the literature; Interviewing experts in the subject; and Conducting focus group interviews.

At first a structured literature review (SLR) based on an adopted approach for systematic literature review from Denyer and Tranfield (2009) has been performed, to answer the preceded RQs. Reviews that are evidence-based like SLRs allow for a higher objectivity of the search results while eliminating error or bias issues (Kilubi and Haasis, 2016). Denyer and Tranfield (2009) defined the following stages: (1) Question formulation; (2) Locating studies; (3) Study selection and evaluation; (4) Analysis and synthesis; and (5) Reporting and using the results – a more detailed description can be found in the literature. For each of those stages the authors proposed more detailed steps to fulfill each stage. The whole methodology is summarized in Figure 1.

Stage (1) has already been completed with formulating the RQs in section 1. Stage (2) and (3) follow in the next section (see section 3). There existing literature will be located and selected based on criteria. The section ends with an overview about existing publications which will be used for stage (4) (see section 4). In stage (4) the selected literature will be screened for relevant technologies and the Technology-Framework will be developed based on the findings and supported through group discussions (see section 4).

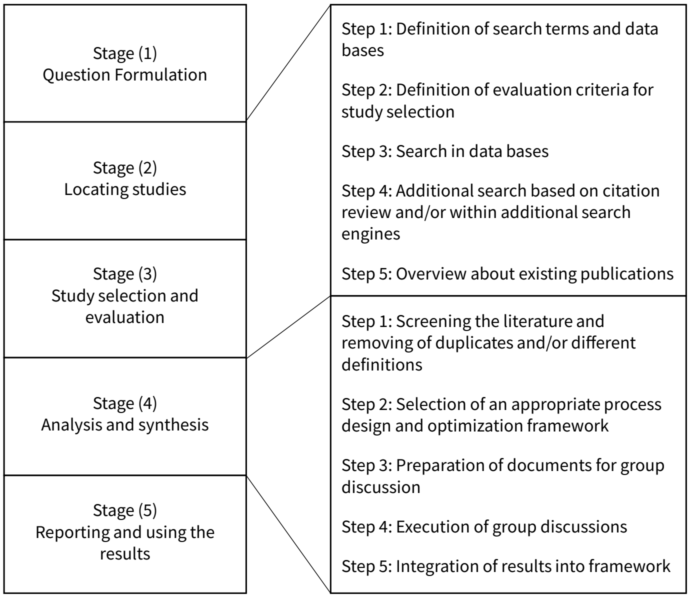

Figure 1: Proposed methodology

3 Research Overview based on located and selected studies

Step 1: Definition of search terms and data bases

During a brainstorming session the key words “Industrie 4.0” and “Industry 4.0” have been selected. The authors chose these words to gather as much literature as possible for collecting mentioned technologies. Both terms are usually connected through an ”OR” operand for the search engines – this leads to results when at least one of the terms is included in the title, abstract or key words. The actual way of keyword combination depended on the used search engine, thus test searches took place to identify the correct way of formulation.

The SLR uses a broad range of databases based on screening existing literature reviews like (Ho, et al., 2015; Kilubi and Haasis, 2016). The following databases have been identified as suitable: IEEExplore, Science Direct, Springer, Emerald, EBSCOhost and Taylor and Francis. Also the publications should be in English or German.

Step 2: Definition of evaluation criteria for study selection

The search in databases and study selection took place in April 2017 and is based on three evaluation criteria, related to the research questions:

Criterion 1: Cluster and/or lists of technologies in the context of I4.0

Criterion 2: Description of a use case in the context of I4.0

Criterion 3: Description of a methodological SC process optimization based on technologies in the context of I4.0

Criterion 1 and 2 have been chosen because technologies in the context of I4.0 are often mentioned within lists or specific use cases. The third criterion has been chosen to include existing literature possibly covering the second RQ.

Table 1: Overview of search results

Database	Results	1. Check	2. Check
EBSCOhost	69	15	0
Emerald	15	4	0
IEEExplore	319	49	2
ScienceDirect	573	66	0
Springer	1.963	123	7
Taylor & Francis	44	11	0
Sum	2.983	268	9

Step 3: Search in data bases

During the search process, a publication has to fulfill at least one of the mentioned criteria when checking the abstracts or in case of a book the introduction and index. Afterwards the remaining literature has been screened in more detail based on the aforementioned criteria. The number of publications in scientific databases can be seen in the following table (see Table 1).

As mentioned above the topic of I4.0 is still an emerging research field (Pfohl, Yahsi and Kurnaz, 2015; Glas and Kleemann, 2016). Which results in only a very limited number of classified research publications with relation to I4.0 and the formulated RQs. Publications about I4.0 can mostly be found in scientific magazines and lower-rated journals or they are studies published by companies or research institutes (Pfohl, Yahsi and Kurnaz, 2015). That's why an additional semi-structured literature search is necessary.

Step 4: Additional search

Because Google Scholar is more complete than other databases (Kilubi and Haasis, 2016), and covers also scientific magazines, lower-rated journals as well as studies it has been used additionally.

Step 5: Overview about existing publications

Applying the aforementioned selection criteria brings additional 23 publications leading to 32 in total. The 32 publications are evaluated in the Table 2 below.

As it can be seen in Table 2, most of the published literature describes potentials of certain technologies in the context of I4.0 or a use case where technologies are already applied in industry. In the third column, a paper is marked if it describes the link between I4.0 technologies and SC processes. Few are marked and all of them fulfill this condition only partly. The reason is that they are describing mainly the potentials of I4.0 technologies in SC processes (Rozados and Tjahjono, 2014; Pfohl, Yahsi and Kurnaz, 2015; Schrauf and Berttram, 2016). None of the identified literature describes a methodological approach which links a SC optimization framework with I4.0 technologies giving guidelines during the SC optimization process.

Table 2: Overview and evaluation of publications

Source	Listing of Technologies	Use case related	Methodological link to SC process (optimization)
Bauer, et al. (2014)	×	×	(×)
Bauernhansl, et al. (2016)	×	×	
Bartodziej (2017)	×		
Bechtold, et al. (2014)	×		(×)
Bauernhansl (2014)	×		
Bienzeisler, Schletz and Gahle (2014)	×		
Bischoff (2015)	×	×	
Bloching, et al. (2015)	×		
Gausemeier, et al. (2016)	×		
Geissbauer, Vedso and Schrauf (2016)	×		
Hausladen (2016)	×		
Hermann, Pentek and Otto (2016)	×		
Horvath & Partners (2017)	×		
Huber (2016)	×	×	
Jäger, et al. (2015)	×		
Kersten, et al. (2017)	×	×	
Obermaier (2016)	×		
Pfohl, Yahsi and Kurnaz (2015)	×		(×)
Plattform Industrie 4.0 (2015)	×		
Roth (2016a)	×	×	
Rozados and Tjahjono (2014)	×	×	(×)
Rüßmann, et al. (2015)	×	×	
Schlaepfer, Koch and Merkofer (2015)	×		
Schrauf and Berttram (2016)	×		(×)
Schwab (2016)	×		
Seiter, et al. (2016)	×	×	
Siepmann (2016b)	×	×	
Wee, et al. (2015)	×		
Wehberg (2015)	×		
Wischmann, Wangler and Botthof (2015)	×		
Wollschlaeger, Sauter and Jasperneite (2017)	×		
Zillmann and Appel (2016)	×	×	(×)

× = Fully fulfilled; (×) = Partly fulfilled

4 Study analysis and synthesis for framework development

After study selection and thus completing step 2 and 3 of the proposed methodology (see section 3 and figure 1) the aim of this section is to identify and select technologies within the field of I4.0 through literature screening and to develop a usable framework, in accordance with step 4 of the proposed methodology (see figure 1).

Step 1: Screening the literature and removing of duplicates/and or different definitions

By screening the literature, 124 artifacts related to I4.0 could be identified which can be interpreted as I4.0 technology. The artifacts will be divided between technologies and I4.0 concepts. Due to the missing definition of I4.0 technology the authors decided to define such a technology as "directly recognizable entity and real existing physical hardware or logical software which is financially activatable and supports or realizes the principles and ideas of I4.0". The next step was to remove duplicate and/or different definitions with the same meaning (see Figure 1). Also similar technologies have been clustered to technology fields to make the later combination with the process optimization framework easier. As a result, the number of technological artifacts could be reduced to 45. Based on that definition, the authors could divide the artifacts as described in the list below (see Table 3).

The concepts are more overarching and abstract ideas or principles which become real by using the technologies (e.g. by using Cyber-Physical-Systems and analytics a predictive maintenance can be realized; using smart devices together with other devices over the internet creates the Internet-of-Things) while the technologies are more tangible through certain hardware, software or objects. Only the technologies on the left side have been used for the later framework. This list also answers the first RQ.

Table 3: I4.0 Artifacts classified in Technology and Concept

Technology	Concept
3D-Printing	Augmented Reality
Actuators	Automation
Analytics	Cloud Computing
Apps	Gamification
Artificial Intelligence (Software)	Horizontal Integration
Autonomous Transport Vehicles	Internet of Things and Services
Big Data	IT-Security
Blockchain	Machine to Machine Communication
Business Management Software/Systems (e.g. ERP, APS)	Predictive Maintenance
CAx (e.g. CAD, CAM)	Smart Factory
Cyber-Physical-System	Smart Grids
Data glasses/Head-Mounted Display	Smart Logistics
Data Mining	Ubiquitous Computing
Digital Shadow	Vertical Integration
Embedded Systems	Virtual Reality
Human Machine Interaction (e.g. Touch interfaces)	
Identifiers (e.g. Barcodes, RFID, QR-Code)	
Image Recognition	
Internet Protocol (e.g. IPv6)	
Mobile Communication (Infrastructure)	
Mobile Devices (e.g. Smart phone, tablet)	
Pick-by-Technology	
Real-time Data	
Robotics	
Sensors	
Simulation	
Smart Objects/Products	
Smart Payment (Software)	
Social Media	
Wearables (e.g. Data glasses, Head mounted displays)	
Wireless Communication (Infrastructure)	
Sum: 30	Sum: 15

Step 2: Selection of an appropriate process design and optimization framework

Due to the focus on SC processes an appropriate process design framework comes from Kuhn (1995). Based on a comparative study only the Process Chain Model of Kuhn (1995) was especially developed for logistic and SC processes (Nyhuis and Wiendahl, 2009) and is part of the Process Chain Instrument. The Process Chain Model enables a holistic visualization and analysis of performance object flows. Deficiencies in the processes can be clarified across hierarchy levels. Another advantage is the strong integration of the employees into process optimization. The process chain representation can be used as a communication medium, since it is a form which is understandable to all, irrespective of the organizational structure. This greatly promotes the acceptance of process changes. During optimization, processes are presented with the design elements system load (sources and sinks), process flow, steering, structures and resources (Kuhn, 2008).

Sources and sinks form the interfaces between the system and the process chain to its environment. Through the sources, performance objects enter the system and leave it transformed over the sink. The entirety of all performance objects that influence a process is called a system load. The process flow can be subdivided into subordinate processes and these can be further detailed as required. Together with the source and sink, they represent the process structure. The process chain elements are subject to various rules and steering rules, e.g. the decision-making scope of neighboring processes. This is referred as steering and is divided into five different steering levels. For the transformation of the performance objects, resources are claimed in the process. The steering levels are responsible for minimizing resource costs through efficient use in the process. The structures describe the classification of process chain elements into a company. These design elements of a process are divided into 17 different potential classes. With the help of the potential classes, processes can be precisely described and investigated for improvement potentials. Through this type of a ”checklist” action alternatives with their respective effects in the process optimization can be opened up (Kuhn, 2008). These 17 potential classes will be explained below (subsequent (Kuhn and Hellingrath, 2002).

Process

Source: Sources are the inputs into a process chain element. They define the input side system load and thus they represent an interface part between the process chain element and the environment. Sources describe the performance objects that must be transformed by the process per time unit.

Sink: Sinks represent the counterpart to sources. They describe which performance objects (information or material) are transformed to the following process chain elements. At the sink, the object triggers a retrieval behavior of the subsequent process.

Process structure: A process chain element represents the process structure with the sources and sinks. The process types are processed/checked, transported, stored or buffered. The process structure can be modified as part of an optimization with the following process chain modulation: Grouping, parallelizing, extending, shortening, eliminating or exchanging processes.

Resource

Personnel: This includes all employees who are available in a process during the operating time. On the one hand, the employee is described in terms of his training, qualification and motivation. On the other hand, the work organization and the flexibility of working and break times are described. These parameters significantly influence the performance of a process.

Area: The resource ”area” is used to list all the operational areas for the transformation of the basic object in a process. It has an impact on investment and operating costs. Small areas lead to an extension of process times or to the limitation of action options.

Stock: The stock comprises the number of basic objects in a process. A distinction is made between materials (e.g. raw materials) and the number of customer or production orders. Stocks are an important control lever in logistics because they have a significant impact on a variety of logistical key figures.

Tools and Machinery: This includes all resources that are responsible for the direct transformation of the object. Typical tools and machinery are production machines and systems or conveyor and storage systems. In a logistical process, transports which carries out the transfer of the object from a source to a sink can also be assigned to this category.

Working aids: This category is assigned to all the resources that are required for the transformation of objects in supportive form. These are e.g. loading aids such as cranes. Particularly in external logistics is the selection of working tools significant.

Organizational means: Organizational means are used to summarize all the resources required for information processing in a process. These include information carriers (e.g. bar codes), information storage, computer architectures, and software programs.

Structure

Layout: The layout, which is often referred to as a topology, determines the arrangement of the work equipment as well as the area and determines the transport links. Thus, the layout significantly influences area usage. In an optimal layout, envelope processes are tried to avoid.

Organizational structure: In this case, the process responsibility is determined within a process chain element. This includes communication and decision-making structures and thus has a significant influence on the ways of information and material flow within the process structure. The goal is to share information more quickly and make resources more flexible to use.

Technical communication structure: This category includes the technical networking of all implemented external and internal systems. These are IT and EDV structures, which are necessary for processing.

Steering levels

Normative: In this category, a company's superordinate values, objectives and standards with reference to a process chain element are described. Thereby, the change of the process is specified. All other potential classes must be able to measure and evaluate these requirements.

Administrative: This level has the task of coordinating the system load with the upstream and downstream process chain elements and assessing future loads. It collects orders based on the sources and sinks and remit them to the normative level. The administrative level also defines current targets, which are aligned with the requirements of the normative level.

Dispositive: This level aims to analyze the system load of the administrative level under existing boundary conditions and optimization criteria. The results are provided to the network level. The orders are assigned to resources and the sequencing of orders is carried out.

Network: The network level coordinates and synchronizes several related processes using autonomous rules to meet customer requirements. The order assignment of the dispositive level is taken over and executed according to the appropriate rules. The difference between the network levels at the administrative level is that the optimized assignment of requests to resources is not taking place, but rather the autonomous rules for the flexible use of interchangeable resources.

Control: The control level has the task of executing the specifications from the network level for a single performance object in a sub-process. The control system performs simple decision rules. At this level, the targets are measured and compared with the relevant agreements.

After selecting an appropriate framework for SC optimization and collecting the relevant I4.0 technologies, the next step is to connect both aspects methodologically. This happens in the next step with the help of group discussions.

Step 3: Preparation of documents for group discussion

For assigning I4.0 technologies to the process design framework the authors chose focus group discussions as an appropriate method. Those focus group interviews capitalize on communication between research participants to generate data (Kitzinger, 1995). This method is useful for exploring people's knowledge and experiences (Kitzinger, 1995). Two documents were created for the focus group discussions. The first document contained the aforementioned technologies and potential classes. Participants should mark for each technology where they see a direct impact on which potential class. The second document was prepared for the second discussion round in which the results were clustered based on the potential classes and participants had to select whether or not they agree on the technology assignment. In case they disagree they also should mention why, as well as when they think a technology is relevant but was not assigned in the first round.

Step 4: Execution of group discussions

Two group discussion rounds took place. At first four experts for topics of digitalization and I4.0 were selected, who are employees at a research institute. The I4.0 technologies and potential classes were briefly explained by a moderator. The objectives of the survey was named, in which the experts should assign the technologies to the various potential classes. The experts should consider which technical key feature of a particular technology could yield the greatest benefit for a potential class with focus on the material flow. It has to be noted that the Process Chain Model was originally designed to model material, information and financial flows within SCs and depending on the kind of flow the meaning of the potential class could change thus the relevance of a technology for a potential class could also change and makes the assignment harder. It was allowed to assign an I4.0 technology to several potential classes. The experts received an overview of the technologies and different potential classes. They were given the opportunity to talk about the task and to communicate their respective opinions. The results were evaluated by the moderator and the discrepancy in the results were presented and discussed. Afterwards, a second focus group discussion took place, consisting of eight participants from research. The participants were different from those in the first round and their knowledge about I4.0 technologies differed. This led to more discussions and created more group dynamic. Finally, the documents were collected by the moderators, evaluated and the improved results were used to form the following Technology-Framework.

Step 5: Integration of results into framework

The following framework is the result of a structured literature review and two rounds of focus group discussions. From 17 potential classes 15 were used to assign technologies. The potential classes ”Normative” and ”Layout” have not been selected by the participants thus they were neglected from the framework. The proposed Technology-Framework answers the last RQ and can now be used within process optimization activities as a supportive tool to stimulate the creativity of the participants (see figure 2 - figure 3). It has to be noted that there may be

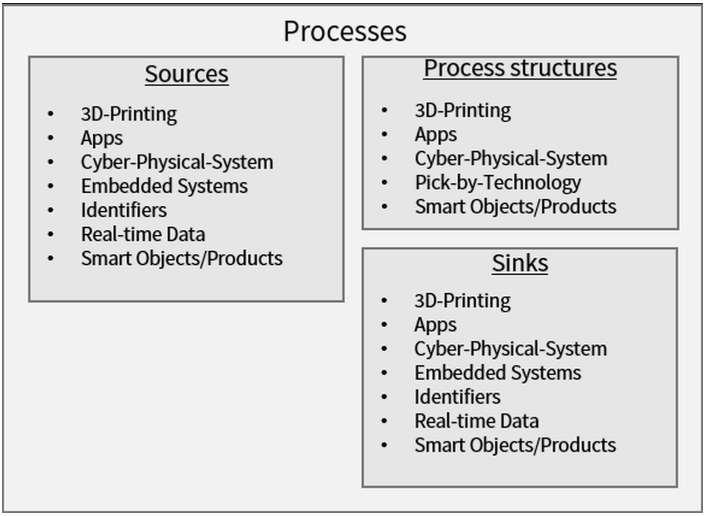

Figure 2: Technology-Framework (1/4) – Processes

cases where some technologies are not applicable in their particular potential class or where additional technologies are suitable.

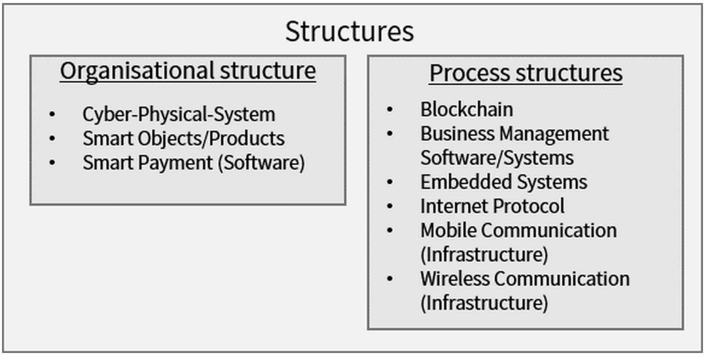

Figure 3: Technology-Framework (2/4) – Structures

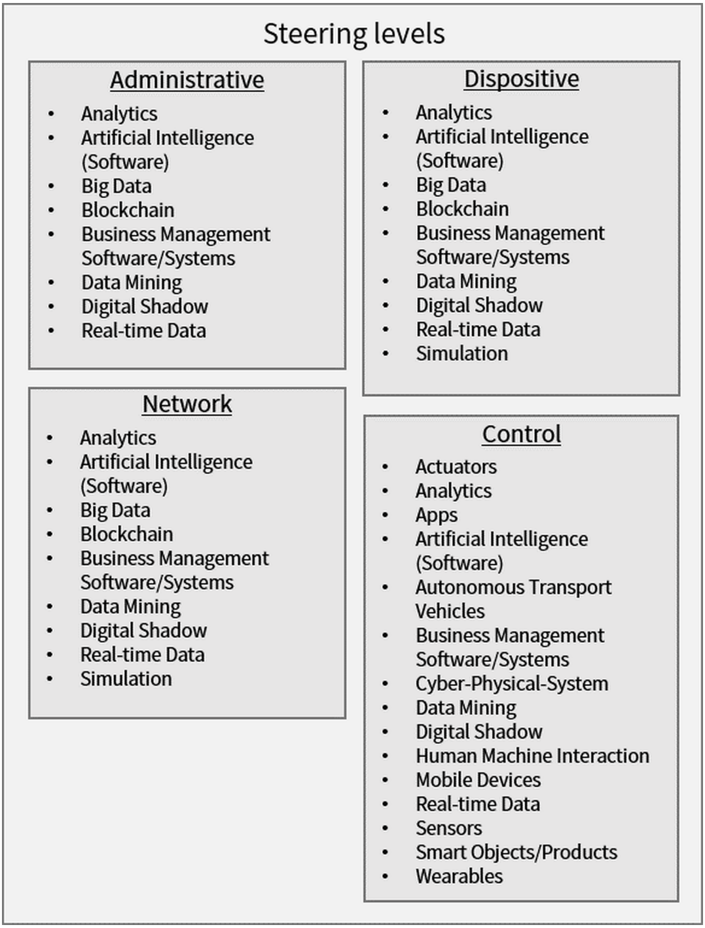

Figure 4: Technology-Framework (3/4) – Steering levels

Resources

Personnel

- Apps
- CAx
- Human Machine Interaction
- Mobile Devices
- Pick-by-Technology
- Real-time Data
- Social Media
- Wearables

Tools and Machines

- 3D-Printing
- Actuators
- Autonomous Transport Vehicles
- Cyber-Physical-System
- Embedded Systems
- Human Machine Interaction
- Identifiers
- Real-time Data
- Robotics
- Sensors
- Smart Objects/Products

Working aids

- 3D-Printing
- Actuators
- Autonomous Transport Vehicles
- Cyber-Physical-System
- Embedded Systems
- Human Machine Interaction
- Identifiers
- Image Recognition
- Pick-by-Technology
- Real-time Data
- Robotics
- Sensors
- Smart Objects/Products
- Wearables

Organisational means

- 3D-Printing
- Actuators
- Autonomous Transport Vehicles
- Cyber-Physical-System
- Embedded Systems
- Human Machine Interaction
- Identifiers
- Image Recognition
- Pick-by-Technology
- Real-time Data
- Robotics
- Sensors
- Smart Objects/Products
- Wearables

Areas

- Actuators
- Cyber-Physical-System
- Embedded Systems
- Sensors
- Smart Objects/Products

Stocks

- Cyber-Physical-System
- Identifiers
- Smart Objects/Products

Figure 5: Technology-Framework (4/4) – Resources

5 Conclusion and Further Research

The paper presents a first approach of linking I4.0 technologies with specific elements of a SC optimization framework based on exploratory research methods. The purpose is to guide practitioners during optimization activities by generally giving an overview about technological options they have and also – by locating improvement potential within the elements of a SC optimization framework – giving an overview on which technologies suite best for certain problems. Linking technologies with certain process characteristics makes it also easier to evaluate the benefits because it is easier to select appropriate process KPIs for measurement. The technologies are methodologically collected from the literature with a structured literature review (see section 2 and 3) and the link to the SC optimization elements has been created with focus group discussions (see section 4).

5.1 Limitations and further research

There is only limited high-ranked literature about I4.0 and regarding technologies available. Due to that the authors mainly used non-scientific publications for the review. The authors also focused only on technologies within the context of I4.0 which may limit the presented technology selection. Also the categorization depends highly on the qualification and number of experts included in focus groups. The selected experts are mainly experienced researchers and very familiar with I4.0 technologies as well as with the Process Chain Model. One way to improve the proposed framework could be to set-up a broad survey or workshops with practitioners and to assign technologies not only for the material but also for the information and financial flow. To give direction within SC optimization activities, the Process Chain Model and its elements have been used due to its focus on logistic and SC processes. The suitability of other frameworks like Event-driven Process Chain (EPC) or Supply Chain Operation Reference-Models (SCOR) should be tested in further research. After creating a valid Technology-Framework, it should be applied in practice.

However, the framework serves as a basis for future SC process transformation. By grouping the technologies around approved categories – originally defined for describing process chain elements – it speeds up the identification and selection of appropriate technologies. The framework is especially designed for practitioners to speed up future transformation processes towards a digitalized SC.

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