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INDUSTRY 4.0 AND ITS IMPACT ON SUPPLY CHAIN RISK MANAGEMENT

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Industry 4.0, also mentioned as the fourth industrial revolution is characterized by a new method of controlling the production processes. Through the employment of new technical approaches, like e.g. cloud computing or cyber physical systems, the supply chain becomes more flexible and more transparent. However, supply chain management will be increasingly faced with new challenges. Resulting from modified framework conditions in Industry 4.0 also new types of risks may occur. Therefore, the paper aims at identifying the impact of Industry 4.0 on supply chain risk management. Possible risks that might occur will be identified and classified. Changes in the content and running of the supply chain risk management process will be analysed and first risk mitigation measures for professional practice will be given.

Keywords: Industry 4.0, supply chain risk management, risk classification, mitigation measures

1. Introduction

The ongoing development of information and communication technologies and their application in industrial companies' production environment has led to a paradigm shift which is summarized in Germany under the term "Industry 4.0". The vision that is pursued with the implementation of new technologies is to achieve an unprecedented level of flexibility in terms of smart production. This enables companies to produce highly customized products in an economic way, meaning without jeopardising a mass producers' profitability (Kagermann, 2014).

Due to changes in business environment caused by Industry 4.0 supply chains will be increasingly faced with new challenges. Moreover,new kind of risks will occur that need to be managed (Kersten et al. 2014). Therefore, the aim of this paperis to identify the impact of Industry 4.0 on supply chain risk management. At first, a brief introduction about the vision of Industry 4.0 and its characteristics is given. Besides, a theoretical background is provided for supply chain management. Afterwards, the effects of Industry 4.0 on the supply chain are analyzed. For this purpose the innovativeness of existing structures and processes will be examined as well as the future challenges the management of supply chains must overcome. Subsequently, the development of Industry 4.0 will be discussed against the background of supply chain risk management. In addition, its associated effects on the established processes will be determined. Finally, the paper finishes with a conclusion.

2. Conceptual demarcation

The following chapter deals with the vision and the conceptual demarcation associated with Industry 4.0. In addition, the concept of supply chain management will be described.

2.1. Industry 4.0

Industry 4.0, also mentioned as the fourth industrial revolution, depends on so-called cyber physical systems (CPS) as key technology.Main characteristic of Industry 4.0 is a new method of controlling the production processes. Today production orders are predominantly centrally controlled and managed. In contrast to this, in the future it will be possible that an order which is released by the end customer moves independently through a dynamic value chain.While it is proceeding it reserves the required materials as well as capacities and heads for the required workstations automatically. After every step the correct execution is examined, possible delays are revealed and countermeasures, e.g. in the form of additional capacities, are organized. However, delays that cannot be prevented are directly reported to the respective customer (Spath, 2013). As a consequence the decisions regarding control of orders are no longer taken centrally. Instead autonomous and selforganizing production units are replacing the conventional passive production units. Key elements in this procedure are the value-adding processes which are adjusted and optimized according to the actual demands by employing real-time information. Hereby, independent production units form an ad-hoc network in the production and lead to highly flexible value-adding processes on higher level(Kagermann, 2014).

These elements and properties have been summarized by the PlattformIndustrie 4.0, a collaborative project of different German industrial federations, in a comprehensive and frequently quoted definition: “The term Industry 4.0 represents the fourth industrial revolution which is a new level of organization and control of the entire value chain throughout the lifecycle of products. […] By connecting humans, objects and systems dynamic, real-time optimized and self-organizing, cross-company value creation networks are formed that can be optimized according to different criteria, e.g. costs, operational availability and consumption of resources” (PlattformIndustrie 4.0, 2013; translated by the authors).

As mentioned before, interconnected CPS are to be considered as a technical precondition for Industry 4.0(Spath, 2013). They are equipped with sensors for gathering environmental data and actuators to affect the environment selectively. Further, CPS are interconnected via digital networks and are capable of accessing data and services which are available worldwide. CPS own multimodal human-machine-interfaces to communicate with external entities (Geisberger and Broy, 2012). This enables the interaction with the current operator or inspector.

Overall, Industry 4.0 can be understood as a poolingof new principles for controlling production/transport systems and as various further developments regarding hardware, software and communication. This combination of different areas and disciplines is most likely also responsible for the far-reaching consequences and the so often emphasized revolutionary dimension of Industry 4.0 (see e.g. Feld et al., 2012). When introducing Industry 4.0 substantial changes for the individual company emerge. The application of technologies associated with Industry 4.0 naturally does not terminate at the boundary of one company, but extends throughout the entire supply chain.

2.2. Supply Chain Management

For several years the supply chain concept isintensively discussedin theory andpractice. In German literature it is often referred to as delivery chain, logistics chain, supplying chain or value chain (Erdmann, 2013; Vahrenkamp et al., 2012). Despite those comprehensive discussions a definition of the term supply chain that is commonly accepted and which unifies all distinct perspectives of the subject to equal extent does not exist. However, for certain properties there is agreement: on the one hand supply chain describes a group of independent companies, on the other hand these companies are interconnected through flows of goods, information and currency in either up- or downstream processes (Mentzer et al., 2001).

This paper follows the definition of Christopher (2011, p. 13) who describes supply chain as *”the network of organizations that are involved, through upstream and downstream linkages, in the different processes and activities that produce value in the form of products and services in the hands of the ultimate consumer”*. Companies that collaborate in a supply chain on a midterm perspective aim to increase the end customer’s benefit. At the same time they strive for a win-win situation that ensues from advantages of mutual exposure to the market dynamics.

To achieve an enduring superiority over competitors in terms of customer preference a better management of the supply chain is required. Supply chain management (SCM) can provide a major source of competitive advantage(Christopher, 2011).A wide range of definitions for the term supply chain management exists, resulting from taking into account the four perspectives, which cover all possible ways of the two fields, logistics and supply chain management (Larson et al., 2007). In this paper the understanding of SCM follows Stock and Lambert (2001, p. 54)who define SCM as *“the integration of*

key business processes from end user through original suppliers that provides products, services and information that add value for customers and other stakeholders".

3. The effectsof Industry 4.0

The following chapter initially examines the consequences on the supply chain caused by an implementation of Industry 4.0. Subsequently, the effects of those changes on the management of supply chains will be analyzed.

3.1. New Structures and Processes in the Supply Chain

The introduction of Industry 4.0 will influence the entire supply chain on a midterm perspective (Bauer et al., 2014; Feld et al., 2012). Especially the production process is undergoing change, in addition to the varying structures. The implementation of Industry 4.0 with its concepts and technical approaches is accompanied bymodifications in the applied hardware, software and communication technology. As a result consequences for the value-adding process in the supply chain occur.

Regarding the implementation of concepts and approaches associated with Industry 4.0 the paper of Ulich (1997) needs to be considered. Ulichdeclaresthat the implementation of computer-aidedproduction systems in companies may only be successful if the process is embedded in a comprehensive concept aiming at optimize the use of technology, the organizational structure and the development of employee qualification simultaneously.

This determination is based on the so-called MTO concept as a socio-technical approach. This concept states that the three sub-elements human (Mensch), technology (Technik) and organization (Organisation) are characterized by mutual dependence.The causality of their optimal interaction needs to be fully determined (Ulich, 1997).This means, within a company the three sub-elements may not be considered in an isolated way. They are interacting with each other during the working processin particular. From this, it can be deduced that the implementation of Industry 4.0 which is frequently only associated with technical innovations should simultaneously also takehuman and organizational factorsinto account.

In the current discussion about Industry 4.0 the practical implementation is often related to numerous key technologies or technology fields. Different lists and descriptions of these terms can be extracted from scientific literature (e.g.Kagermann, 2014; Blanchet et al., 2014; Bauer et al., 2014) which only show to some extend identical terminology. Therefore, at the current state it is not possible to comprehensively differentiate between the technologies used and affected by Industry 4.0(Bauer et al., 2014). For this reason in the following often-quoted key technologies and their impact on the supply chain will be described.

As explained in chapter 2.1 CPS are substantial for Industry 4.0. Apart from this, also terms like Big Data, Cloud Computing, intelligent products and machines are pointed out. In principle, these technical innovations create self-organizing, cross-company value-added networks by enabling an interconnection between humans, objects and systems (PlattformIndustrie 4.0, 2013). How these networks are designed in detail strongly depends on the one hand on companies involved and on the other hand on the industry (Bauer et al., 2014).

As a basic technology CPS do notfundamentally change the tasks of machines and equipment used in production.However, the way in which they are operated and controlled reflects asignificant development; from a hierarchically organized system to a decentralized and semi-autonomous collective. Further, the interaction between machine and operator is transforming. As a result, new ways of communication in form of mobile devices, such as smart phones and tables will be integrated into the manufacturing area. Via innovative applications a larger volume of information is available for the employees in real-time. This significant high volume of data which is in addition increasing by intelligent objects and by ubiquitous sensors and other producers of data requires a suitable infrastructure for aggregation and analysis. Only in this way companies are able to assemble produced raw data to a real-time image of the production and to use it for their decision process. Thus,today companies need to face the question to what extend they have already invested in the required infrastructure and in the required know-how and which further steps in development still need to be taken.

In the processes of data storage a trend towards cloud computing can be observed (KPMG, 2014). This means that data is not stored on local desktops or serversanymore, but instead on virtual platforms across different locations. These virtual platforms can be owned and run by the companies themselves or by specialized service providers. Also, applications do not require an installation onto local computers in

the future, but will be instead ran from the cloud on all devices (Bauer et al., 2014). However, these possibilities imply a modification of the conventional infrastructure and the organizational configuration as well. In particular, companies from industrieswhich are characterized by highly fluctuating demands gain a profit from cloud services as they are comparatively reasonable and available at any time. Yet, this increase in flexibility requires again a qualification of staff and an alignment of the organization.

Through the employment of the technical approaches of Industry 4.0 the supply chain becomes more flexible and more transparent. In addition, possibilities for customers to make use of (personalized) functionalities are increasing allowed by customized mass-production that operates in an economically profitable way(Baum, 2013).This requires an exchange of information between the supply chain partners that is far beyond today's level. Besides the described data collection, data storage and processing, a reliable and safe data transmission via related networks is a key factors for success. An increased flexibility can only be achieved if the requirements in form of detailed demand data are known.

The increased data volume and its availability requiresat the same time to reconsiderthe information handling in order to exploit the potentials of Industry 4.0. Assuming a company has committed itself to a restrictive information policy towards its suppliers and customers in the future this company might face requirements to loosen those restrictions. Only then a far reaching integration of all supply chain partners on informational level will be brought along by Industry 4.0 and allows as a consequence new forms of collaboration.

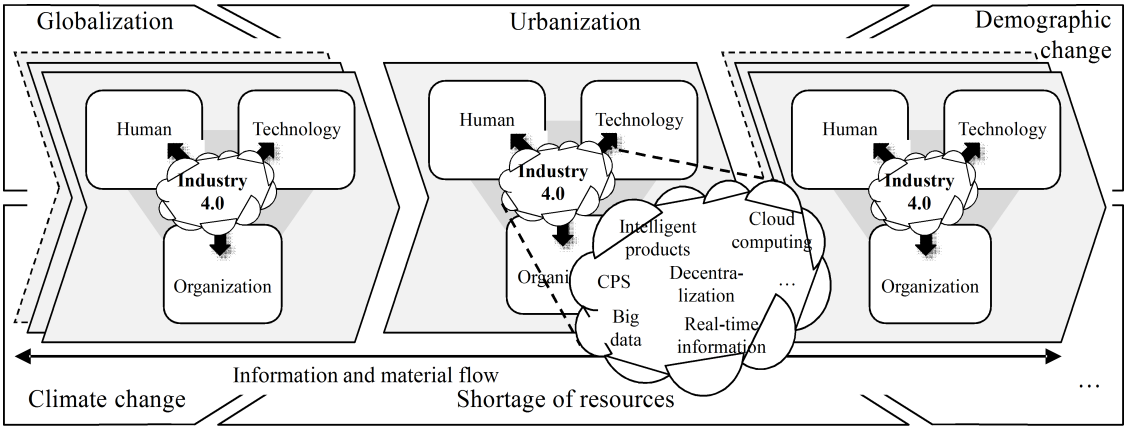

*Figure.*Integration of Industry 4.0 in the supply chain

Figure 1 summarizesthe integration of Industry 4.0 in the supply chain graphically. On the one hand it illustrates the supply chain which is challenged to secure the flows of information and goods influenced by different megatrends, like globalization, demographic change or shortage of resources. Here the flow of information is extremely important, since it is even more far reaching than before due to the use of new technologies. On the other hand it shows the strong impact that key technologies of Industry 4.0, e.g. cloud computing and CPS have on the structures and processes within a company and the entire supply chain. In particular,the impact on the interacting sub-elements human, technology and organization must be emphasized.

3.2. NewChallenges for Supply Chain Management

The implementation of Industry 4.0 does not only bear challenges for the supply chain but also for its management. Hence, the paradigm shift from centralized to decentralized control leads to severe changes for SCM as well. For example, established industry sectors might vanish, caused by the new arrangement of value-adding processes. As a result, new and extensive fields of action arise and collaborations that have been unknown so far become possible or even essential (ten Hompel et al., 2014b). Furthermore, future production structures will differ in terms of responsibility assignment and legal competencies (VereinDeutscherIngenieure, 2014). This is a consequence of the progressive integration of supply chain partners and the arising action fields and collaborations for which the framework conditions need to be determined.

Due to further expanding global production networks the management approaches concerned must bedeveloped further (ten Hompel et al., 2014a). Today's common practice of focusing on one manufacturing location becomes insufficient. Instead, it should consider the entire production network in

a high level of detail. Sub-systems that had been independent before will be connected,synchronized and interactingwith each other. Subsequently, flows of material can be redirect at short notice and therefore it can be reacted quickly to unforeseen changes in demand. Meaning, the entire production network can be managed like anindividual location today (Bauer et al., 2014). Those decisions regarding the material flow are influenced from the logistics cloud as virtual point of central control. Thus, the usage of cloud-based information technologies becomes integral part for the SCM and its work content (ten Hompel et al., 2014b).

Further, SCM is influenced by the separation of the normative and operational level which is conditioned by the new way of control and operation. By giving great autonomy to the production units on operational level it will be only necessary to interfere in the material flow to a minor degree. Therefore, SCM predominantly takes strategic decisions.Less orno detailed layouts or the like may be needed on the normative level which makes a significant difference to the current practice (ten Hompel et al., 2014a). This leads to the conclusion that SCM as business function acts in Industry 4.0 as a controlling entity on operational level and predominantly takes active decisions on normative level.

Additionally, changes are made concerning the prognosis of systems' target achievement. As a result of the independent production units only a statistical statement regarding its fulfilment will be possible in the future. That is because a central control and the associated predetermination will not be given (ten Hompel et al., 2014a) . This must be taken into account, however it should not have large impact on the management of the supply chain.

On the contrary,a significant impact can be observedwhen considering inventory management.Inventories are an important tool, although they are hard to foresee,due to sudden changes in order volume. Unfortunately, they require a certain investment. But by using reliable real-time information and an increased flexibilitythe costs for inventory can be reduced by 30 to 40 percent in Industry 4.0 (Bauernhansl, 2014).

4. Supply Chain Risk Management within the Fourth Industrial Revolution

Resulting from modified framework conditions in Industry 4.0 also new types of risks may occur. Those risks associated with the supply chain will be of focus in the following chapter. Subsequently, changes of the supply chain risk management process in Industry 4.0 will be analyzed. The chapter concludes with giving first recommendation for professional practice.

4.1. Categorization of Arising Risks in the Supply Chain

The association of companies forming a supply chain is on the one hand connected with an increasing dependency between those partners and on the other hand the number of potential supply chain risks grows as well. Possible consequences from those risks depend on the intensity of relationships between the companies. In order to handle supply chain risks and their negative effects in a professional way a risk management is of great importance. Generally,risks in decision theory are referred toas variation in the distribution of possible outcomes, their likelihood, and their subjective values(Jüttner et al., 2003). Therefore, risk is associated with a positive as well as a negative outcome.Since, risk is a result of the uncertainty of future outcomes, this approach is also considered as cause-related perspective(Gabler-Wirtschaftslexikon, 2004). In a broader sense, uncertainty covers the term risk as well as uncertainty in a narrower sense. Further, Knight (1921, p. 20) distinguishes between "measureable" and "unmeasurable" uncertainties. In contrast to the cause-related perspective the effect-related perspective puts the main emphasis on risk consequences. Here the risk is understood as the "possibility of targetshortfall" (Braun, 1984, p. 23). From that in business administration it is assumed to be a potential damage or loss that could lead to a targetshortfall in the company. In this paper risk is defined as a product of the likelihood of a negative event and the extent of damage that can be expected (Holzbaur, 2001).

It is a key factor for the company's success to identify and mitigate risks in the supply chain. Therefore, it is necessary to fully identify emerging risks in Industry 4.0 and to approach them with suitable measures. Only then companies will be successful on a long-term basis. For a systematic identification and consideration it is useful to classify risks by different categories. This work follows the classification of Christopher and Peck (2004) dealing with supply chain risks, since it is frequently applied in literature commonly accepted. In here, the classification of categories is carried out according to five possible risk sources: supply, process, demand, controland environment (Christopher and Peck, 2004).

In view of supply chain risks caused by Industry 4.0 comprehensive descriptions or discussions cannot be found, until now. Merely a few risks in the general context of Industry 4.0 and its implementation are being explained in scientific literature. For that reason, the general risks mentioned were analyzed by the five categories from Christopher and Peck (2004) and classified respectively to the greatest possibleextent. Additionally, further risks were added to the categories that originated from discussions with experts (see figure 2).

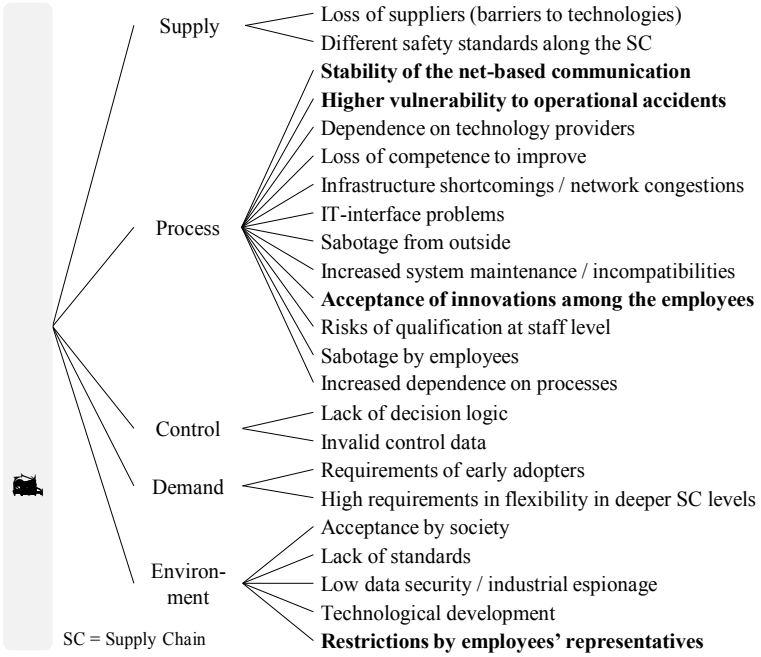

Figure. Supply Chain Risks within Industry 4.0

The here mentioned list does not claim to be complete, but provides a few practical approaches. In the following risks highlighted in figure 2 are explained exemplarily.

The *stability of the net-based communication* marks a significantrisk for the production process. Rapidly increasing volume of data and its necessity for the decision process leads to the assumption that broadband communication form the backbone of Industry 4.0. In order to realize a reliable supply chain the highest availability of the communication systems as well as the maximum in network security avoiding any sort of cyber attacksmust be achieved (Bauer et al., 2014).

Further, safety of the employed staff is a critical issue for a functioning supply chain. As a result of autonomous transport systems for example this safety could be jeopardized by a *higher vulnerability to operational accidents*(Liggesmeyer and Trapp, 2014). This creates a possible process risk.

Furthermore, when implementing Industry 4.0 the employees' right to participate maynot be ignored. It is tobe considered as basis for *acceptance of innovations among the employees*(Bauer et al., 2014). The deriving process risk results from absolutely necessary support of the employees to achieve an efficient and stable supply chain. Correspondingly, also *restrictions by employees' representatives* operating on a cross-company level must be prevented by involving all parties in an early dialog. Otherwise the environmental risk in form of paralyzing restrictions could occur. Reason for those restrictions could be for example the fear of staff reduction or forced flexible working hours(Kurz, 2013).

Due to limited space further risks cannot not be discussed in detail. However, from a general perspective it appears to be true that the risk examination should be conducted for every company individually. Reason for that are differing supply chain designs, industrial branches and situational aspects. Further, a temporary aspect of those risks must be considered. Depending on the level of implementation supply chain risks have different probabilities of occurrence and cause more or less damage. For example it is to be expected that the risk of qualification will arise in the beginning of Industry 4.0 more extreme than at a later point in time. Same applies to the risk of missing standards which will be reduced by the establishment of commonly accepted solutions as time passes.

4.2. Effects on the Supply Chain Risk Management Process

For the systematic management of identified risks in the supply chain a risk management process has to be established. As shown in figure 3 the process contains four steps, namely risk identification, risk analysis, risk handling and risk control(see e.g. Kersten et al., 2011).

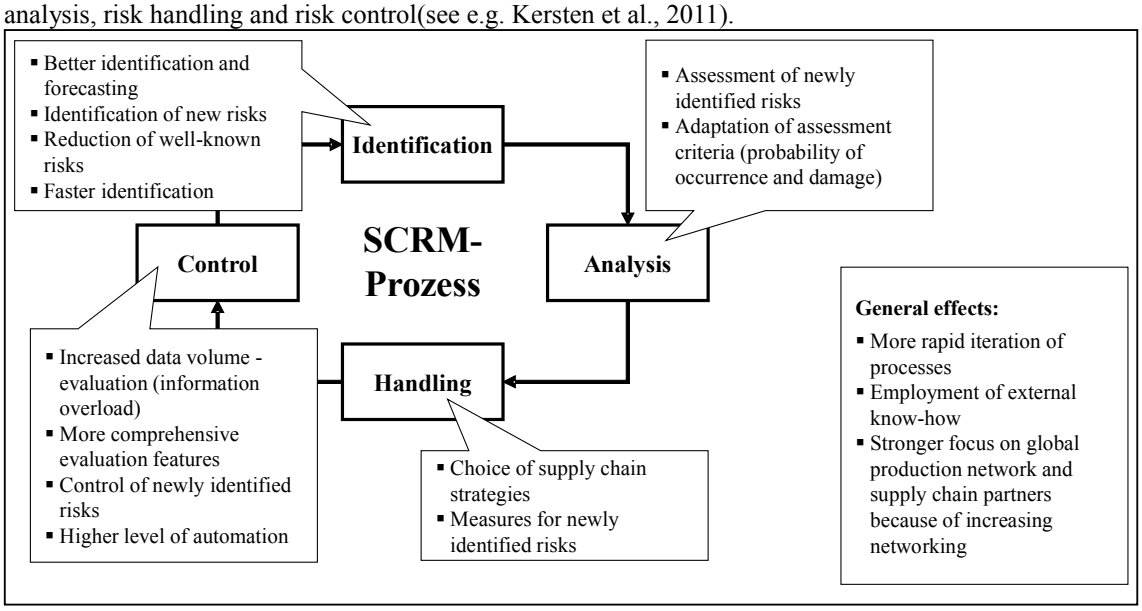

*Figure 3.*Risk Management along the Supply Chain in Industry 4.0

During the step of risk identification all supply chain risks are being located. Here, different approaches for classifying risks can be used. Due to altered framework conditions in Industry 4.0 multiple changes occur compared to the conventional supply chain: by using innovative key technologies a significantly higher amount of information is available in real-time that needs to be processed. With this comprehensive database on the one hand,risks can be identified in a simpler and faster way.On the other hand risks and their effects can be predetermined more accurately. Caused by the innovative infrastructure new risks at the multimodal human-machine interface may occur that have been previouslyunknown. The self-controlling logistics processes could lead to an increase of the vulnerability to operational accidents. Yet, well-known risks such as delays in the production process could be reduced by detailed forecasts.

In the second process step, risk analysis the previously identified supply chain risks will be assessed by determining the probability of occurrence and the potential damage. In addition to the conventional supply chain risks also newly developed risks need to be assessed. Due to the large volume of data that derives from the entire supply chain potential damages and their probability of occurrence can be predicted more precise. However, new assessment procedures might be needed in order to manage the complexity of these scenarios. Also an adaptation of assessment criteria (probability of occurrence and damage) seems conceivable.

The third process step that deals with risk handling ensures the determination of supply chain strategies and measures for managing the afore identified risks.Also in the context of Industry 4.0 it must be differentiated between avoidance and mitigation of risks (cause-related) or between risk limitation, risk sharing and bearing their own risks (effect-related) (Pfohl, 2008). Nonetheless, it is necessary to modify further measures to be taken according to the new framework conditions. A detailed explanation follows in chapter 4.3.

In the fourth process step which containsthe risk control a verification of the measures taken is being conducted regarding their effectiveness and their efficiency. In here the increased data volume that results from the application of the key technologies can be used for the evaluation. Although the possibilities to assess the risk situation are increased by the enlarged volume of data. Butnot all data is of great relevance and could lead to a so-called "information overload". This would result in an increasingcomplexity in the control process. The transmission of relevant data however is connected to a higher level of automation which makes the exchange between the individual partners more easy.

Generally, the SCRM process should be iterated on a regular basis, because change in the risk landscape could evolve at any point in time. Due to the altered framework conditions caused by

Industry 4.0 a more rapid iteration of the process becomes necessary, because relevant data is constantly exchanged and modifications can be predicted far in advance.

Further, the employment of external know-how in the individual process steps of the SCRM will be required, since the applied instruments and techniques demand a high level of specialized capabilities in the work force that needs to be brought into operation within shortest time.

4.3. Approaches for Professional Practice

As a result of different new risks that might occur in the supply chain in the context of Industry 4.0 a revision of all conventional measures taken so far is required and an introduction of further actions must be considered. As an example table 1 summarizes some measures that are related to the risks identified in chapter 4.1. Those measures result from a workshop of the authors, corroborated byresults of discussions with experts. This compilation was also combined with measures named in scientific literature.

Table 1. Measures for Managing Supply Chain Risks in Industry 4.0

Supply	
Loss of suppliers (barriers to technologies)	Early information processing to suppliers about technological and structural changes Demand for proof of implementation
Different safety standards along the SC	• Establish uniform standards in cooperation with the principal players/ industry associations of the SC
Loss of bargaining power over suppliers	Taking technological requirements into account while designing the SC Contractual arrangements
Process	
Stability of the net-based communication	Regular checking of communication networks (stress test, vulnerabilities, etc.) Redundantequipment
Higher vulnerability to operational accidents	Regular staff training in occupational and operational safety Establish security standards in corporate culture
Dependence on technology providers	Respectively employment and training of own employees with expertise
Loss of competence to improve	Regular staff training to increase methodological competence
Infrastructure shortcomings / network congestions	Development of alternatives Future-proof dimensioning of infrastructure
IT-interface problems	Establishing of standards
Sabotage from outside	Increasing and regular checking oftechnical standards
Increasedsystem maintenance / incompatibilities	Regular system maintenance and development of alternatives Develop concepts for trouble-free maintenance
Acceptance of innovations among the employees	• Enhance motivation by setting incentives, e.g. promotion possibilities resulting from training Involvement of employees in arrangement
Risks of qualification at staff-level	In time and regular training of staff
Sabotage by employees	Setting incentives, motivation of employees Monitoring mechanisms to prevent abuse
Increased dependence on processes	Decoupling of processes and creating of buffers
Control	
Lack of decision logic	Thematic management training (e.g. risk and complexity management, IT) Full test in pilot implementation
Invalid control data	Development of compatible test algorithms Provide emergency strategies
Higher complexity	Modularization of corresponding processes
Demand	
Requirements of early adopters	Timely involvement of early adopters into the process ofchange Regular exchange of experience
High requirements in flexibility in deeper SC levels	Timelydeterminationof needs for flexibility • Updated knowledge of market developmentand communication tothe supplier as well as to the customer
Environment	
Acceptance by society	Communication of advantages corresponding to Industry 4.0 at events Delegate dialogue with stakeholders to interest groups
Lack of standards	Development of uniform standards within the industry by working groups Discussion in industry associations
Lowdata security / industrial espionage	Increase of safety regulations (virus program, password, etc.) Consultation of extern service providers Exchange only necessary data
Technological development	Establish technology partnerships Diversification regarding technologicalsystems

Restrictions by employees' representatives	Involvement of groups of interest into process of change

The measures listed in table 1 reveal that an adaptation to Industry 4.0 also requires far reaching activities of technical nature. Only then a secured communication can be established that guarantees data being correct, complete and available in time.

New methodical and technical approaches are necessary that allow an evaluation and control of the information and communication systems and that further help to quantify any associated risks. The development of new security standards which meet the challenges of the connected and embedded systems and which are resist against cyber attacks at the same time seems to be indispensable (Fallenbeck and Eckert, 2014).When choosing the measures and developing new approaches the MTO concept that was described in chapter 3.1 should be considered sufficiently. Apart from the technical and organizational aspects especially the employees should be involved when implementing Industry 4.0.

Furthermore, it is also noted that while choosing any measures also the level of implementation should be considered. Risks occurring in the introduction phase differ strongly from those in a steady-state condition.

5. Conclusion

The aim of the paper was to identify the impact of Industry 4.0 on supply chain risk management and to compile measures to support entrepreneurs in managing these new risks. The implementation of Industry 4.0 has shown that the connection of humans, objects and systems formed to dynamic, real-time optimized and self-organizing, cross-company value creation networks, can have an impact on the entire supply chain.Through the employment of the technical approaches of Industry 4.0, e.g. cloud computing or cyber physical systems (CPS) as key technology, the supply chain becomes more flexible and more transparent. At the same time, the fact of increased data volume and availability in real-time requires new infrastructures and an adapted handling of information. Supply chain management will be increasingly faced with new challenges, because new handling fields will arise, great autonomy is given to the production and decision-making competences will be transferred. Relevant controlling instruments must be developed further for the intended purpose, considering the high level of detail.

The analysis of supply chain risk management against the background of Industry 4.0 has shown that numerous new risks may occur due to the changing conditions. Along with supply, control, demand and environment risks it was determined that process risks occur more frequently in Industry 4.0. Also, the content and the running of the supply chain risk management process will change, which is not least due to the availability of real-time data. Each step of the supply chain risk management process can be run faster. Therefore, existing instruments and measures must be adapted. Finally, a miscellaneous number of measures has been compiled which can be used by companies in order to manage the identified new risks. Additional mitigation measures must be developed even further in the future. Though, the own employees should be involved in designing to gain acceptance of the processes at an early stage and to ensure company's success in the long term.

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