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Framework for Digitalized Proactive Supply Chain Risk Management
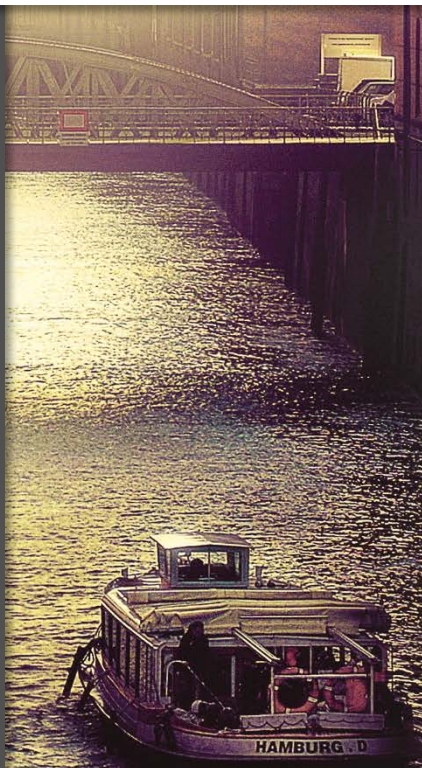
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Framework for Digitalized Proactive Supply Chain Risk Management

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In order to initiate proactive measures and to prevent the actual occurrence of risk events a digitalized and proactive supply chain risk management is needed. Existing approaches for digitalized and proactive SCRM are investigated by a systematic literature review and completed by a requirements engineering. Furthermore frameworks for SCRM are reviewed and the fulfillment of the requirements is checked. These results are applied to develop a digitalized and proactive SCRM framework. The findings in this paper are a profile of requirements and a framework, which enables a proactive management of forthcoming risks. Therefore an application of risk prediction and quantitative risk assessment in context of digitalized SCRM is used. The developed framework includes an adapted proactive SCRM process containing digitalized SCRM phases and digitalized SCRM methods, inter alia early knowledge and early assessment.

1 Introduction

Due to high outsourcing rates manufacturing companies are highly dependent on the performance of suppliers and supply chains (SC). Supply chain risks (SCR) can cause disruptions which lead to glitches. Glitches result in demand and supply mismatches and can have propagating effects on the entire SC. SCR is defined as the likelihood and impact of unexpected risk events which influence any part of the SC (Ho et al. 2015 p. 5035). A company's SC performance is depending on the degree of implementation of a supply chain risk management (SCRM) system (Thun & Hoenig 2011 pp. 246) and of assignment of responsibilities. Due to the crucial impacts and thereby high importance the management board should bear the responsibility for SCRM system planning, implementing and operating. The impact and probability of SCR occurrences for companies can be minimized with proactive SCRM systems and a high efficiency of company's SC processes can be enabled. The need for proactive SCRM has been identified by scientific researchers and managers in companies practice. Several recent published findings which cover the topic are available, while in the previous years before 2010 just a few papers were published. Due to the digitalization of SCs as well as the development of new technologies and SC partner collaborative approaches new potentials for proactive SCRM arise. In order to remain competitive and for economical production, companies have to deliberately take risks and accept a certain insecure risk situation. This publication investigates proactive SCRM approaches which accept the risk situation and focus on the management of individual forthcoming risk events.

1.1 SCRM Research Needs in the Field of Digital Transformation

Although the SCRM research field has gained a lot of attention during the last decade, the field of digitalized SCRM and proactive SCRM development is not considered adequately (Kırılmaz & Erol 2017, Kache & Seuring 2017 p. 20). Besides the scientific research gap, the need for proactive SCRM approaches in companies practice is urgent due to high number of risk events and the limitation to reactive firefighting systems (He et al. 2015 p. 1005, Kilubi & Haasis 2016 p. 66, Tang & Musa 2011 pp. 31). There have been some analyses conducted reviewing the SCRM literature in the recent past, which have a specific focus and thereby don't serve the objective of this publication. The past reviews have been focused on the purpose of SCRM studies (Vanany, Zailani & Pujawan 2009, Sodhi, Son & Tang

2012), definition of specific SCRM terms (Ho et al. 2015, Singh & Wahid 2014), risk classification (Qazi, Quigley & Dickson 2015, Tang & Musa 2011, Singhal, Agarwal & Mittal 2011), the SCRM process (Ho et al. 2015, Qazi, Quigley & Dickson 2015), risk sources (Kilubi & Haasis 2016), strategic changes in the field of SCRM (Ghadge, Dani & Kalawsky 2012), quantitative models for SCRM (Heckmann, Comes & Nickel 2015, Fahimnia et al. 2015) and relationship between SCRM and performance (Kilubi & Haasis 2016). The SCRM procedure has become a key issue of this research field. Most literature review publications show an analysis of SCRM publications in general, whereas the focus on proactive SCRM and the Digital Transformation of SCRM is missing. There is a research need for quantitative and model based proactive SCRM approaches (Kırılmaz & Erol 2017 pp. 62, Tang & Musa 2011 p. 32). These models should take interdependencies between dynamic risks and the risk propagation along the SC into account (Qazi, Quigley & Dickson 2015). In addition to material flow, for SCRM information flow and financial flow ought to be considered in depth (Tang & Musa 2011 p. 32). In addition to the analysis of Schlüter, Diedrich & Güller 2017 for digitalized approaches for the SCRM phases a comprehensive framework is needed which includes digitalized approaches and applies them for a proactive SCRM procedure.

1.2 Objective and Research Methodology

The objective of this paper is the development of a proactive SCRM framework which takes the Digital Transformation of the environment and of SCs that is currently taking place as well as the arising potentials for SCRM into account. In order to meet this objective, a Systematic Literature Review (SLR) is conducted. Due to the small number of publications regarding proactive SCRM, the keyword search of the SLR is extended to proactive SCRM and SCRM Frameworks. This paper explores the above described research gap regarding scientific approaches for proactive SCRM.

Hence, a SLR was conducted, targeting to collect and analyze relevant publications regarding proactive SCRM approaches. This SLR is used for the analyzation of proactive SCRM approaches and for the description of the research gap concerning proactive SCRM. For the following development of a proactive SCRM framework a requirements gathering has to be conducted. Requirements were derived from SLR findings and the results are applied to develop a digitalized and proactive SCRM framework. In addition specific features of risk assessment will be outlined and suggestions for further research conclude this paper.

2 Perspectives in Proactive SCRM

2.1 Digitalized SC Function as an Enabler for Advanced SCRM

New technologies enable the digitalization of SCs. These technologies are for example near field communication (NFC), radio frequency identification (RFID), barcode and machine sensors. New technologies are applied in research fields which are part of Digital Transformation and Industry 4.0, such as cyber-physical systems, cloud computing, smart factory and internet of things (Kersten, Schröder & Indorf 2015). From these applied technologies in supply chain management and logistics new data sources arise which enable a data driven management of SCRs by application in appropriate methods. For efficient SCRM an advanced SC information management is required, which contains a supplier data base including master data of n-tier supplier, production sites, and further specific knowledge. The knowledge management and visualization of SC and the SCR information processing in the context of Digital Transformation and the associated data generation is still an unexplored research field (Fan et al. 2017, Biswas & Sen 2016). Current key challenges of the Digital Transformation of SC and SCRM are data islands, silo mentality and insufficient cooperation let alone collaboration of data availability. The Supply Chain Shadow as a virtual representation of a SC is enabled by the digitalization of SCs and the accompanying availability of real-time data (Henke 2017). The concept of the Supply Chain Shadow uses the available data in a virtual information and knowledge transfer.

2.2 Digitalized Proactive SCRM Approaches

The digitalization of SCRM is based on digitized SCs and enhanced technologies and methods. Available real-time data regarding SCRs result from applied technologies. New potentials for digitalized SCRM have been analyzed by Schlüter, Diedrich & Güller 2017, their findings are summarized in an overview of existing approaches which take digitalized methods for the phases identification, assessment, treatment and monitoring & control and thereby a digitalization of the SCRM procedure into account. A resulting change in the SCRM procedure is the parallelized pass through of risks in the digitalized procedure (Schlüter, Diedrich & Güller 2017 p. 6). Thereby the phases don't have to be processed sequentially by long-term committees anymore and risks can be handled simultaneous in different phases.
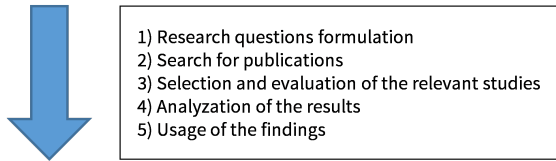
1) Research questions formulation
2) Search for publications
3) Selection and evaluation of the relevant studies
4) Analyzation of the results
5) Usage of the findings

Figure 1: SLR method

3 Systematic Literature Review for Proactive SCRM

The SLR conducted in this paper is based on the methodical approach described by Seuring & Gold 2012, as can be seen in figure 1. A SLR is a transparent, reproducible scientific method which targets to cover the state of research with a specific research focus defined by the following research questions (RQ):

RQ1: Do the proactive SCRM frameworks, methods or approaches correspond with the introduced definition for proactive SCRM?

RQ2: Do the approaches take new potentials for proactive SCRM arising from the Digital Transformation into account?

RQ3: Which requirements for a proactive SCRM Framework can be raised?

Found publications are selected as relevant by use of assessment criteria (AC):

AC1: Future-oriented methods for the phases of the SCRM process

AC2: Management of forthcoming risks while accepting the risk situation

AC3: Potentials for SCRM which result from the Digital Transformation of SCs & SCRM itself

AC4: Further aspects of proactive SCRM

The first AC shall bring attention to forthcoming risks. The AC2 has to be described further for a deeper insight: The bearable risk situation of a company depends on the SC dependency, buffers, flexibility and further aspects, whereat no guidelines exist that describe how much risk a company should accept. The higher the accepted risks are, the more chances can be taken and the higher is the impact of potential risks. The company's risk situation is accepted to gain chances by accepting risks and this paper targets at not changing the risk situation and existing

109 / 832 identified references regarding keywords by database search

Duplicates removed

References excluded (title, abstract, conclusion)

References included by cross-referencing

55 / 85 identified eligible references remaining for full-text-analysis

References excluded (full text review)

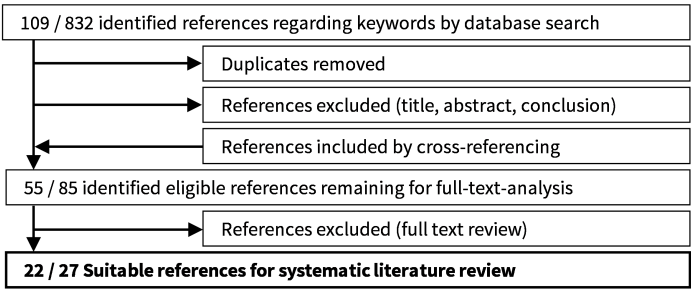| **22 / 27 Suitable references for systematic literature review** |
|---|

Figure 2: Number of references

structures. Therefore the optimization of the risk situation by preventive management and not taking the risks is explicitly not looked for. The third AC refers to the application of new technologies and methods for deeper risk knowledge and management improvement. AC4 targets the open search for further aspects or approaches which serve the proactive SCRM. SCRM framework publications are assessed based on in-depth description of reactive SCRM frameworks. After selection of papers the full paper review process and the content analysis have been carried out. These findings are introduced in the following section.

3.1 Analytical Description of Publications

For answering these research questions appropriate publications are reviewed with the year of publication between 2000 and June 2017. The applied keywords for database search are proactive supply chain risk management and framework supply chain risk management. The database SCOPUS.COM was most suitable for this search, as Fahimnia et al. 2015 has described before. SCOPUS includes e.g. Wiley, Taylor & Francis, Emerald, IEEE Xplore and Springer. Thereby the search is open to several journals and conferences and limited by the application of the defined keywords.

The resulting numbers of publications are shown in figure 2, whereby the first number refers to proactive SCRM and the second number to SCRM framework publications. The analysis of the distribution of suitable publications over the year
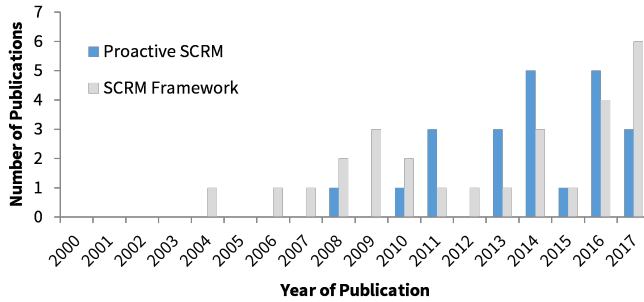
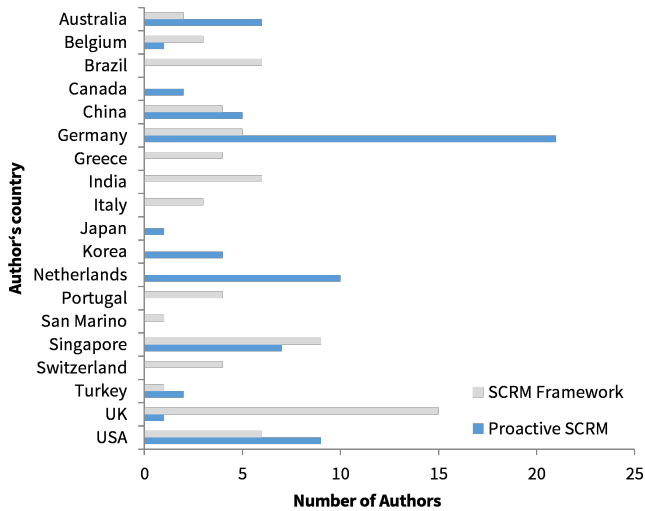Figure 3: Years of publication of suitable publications

Figure 4: Authors countries of suitable publications

of publication is shown in figure 3. This analysis shows a significant research interest in proactive SCRM since 2008. There are just a small number of approaches for proactive SCRM in scientific literature available, which confirms the research gap for proactive management.

The suitable publications are published in Journals (15/18) and conferences (7/9). This shows that conferences are an important research platform for SCRM and shouldn't be neglected in SLR. The countries of publishing authors are visualized in figure 4.

3.2 Content Analysis of Proactive SCRM Publications

The suitable SCRM framework publications show SCRM procedure approaches, but none of these are proactive approaches. In literature the terms reactive, preventive and proactive SCRM are often used, but the definition and understanding of the term proactive SCRM differs in the literature even though many publications refer to proactive SCRM (Qazi, Quigley & Dickson 2015). Many publications use the term "proactive" but actually don't meet the ACs for proactive SCRM and are rather preventive approaches. The term proactive SCRM is often applied to approaches which should be assigned to preventive SCRM, because these approaches change SC structures, apply alternative strategical approaches, for example dual sourcing, and by not taking on risks any longer improve the risk situation. None of the reviewed publications give a definition for proactive SCRM. The author's understanding and definition of proactive SCRM is as follows: Proactive SCRM approaches target to gain action time for management of individual forthcoming SCR and thereby can be described as ex ante management while accepting the risk situation of a company in a SC network. A common, but not defined, understanding can be found in applicable publications, such as Rotaru, Wilkin & Churilov 2014 and Leveling et al. 2014. The remaining suitable publications meet at least one AC (8), whereas no publication meets all ACs, as can be seen in figure 5.

To gain the ability of proactive SCRM a high level of technical abilities has to be achieved. Furthermore the research field of digitalized and proactive SCRM is fast growing, so that the existing reviews are no longer up to date, which was confirmed by the conducted review.

Analysis of Existing Proactive SCRM Approaches

AC 1: Future-oriented methods for the phases of the SCRM process
Li et al. 2010; Jung, Lim & Oh 2011; Schmitt 2011; Goh et al. 2013; Marvin et al. 2013; Kurano, McKay & Black 2014; Leveling et al. 2014; Rotaru, Wilkin & Churilov 2014; Schlüter & Sprenger 2016; Kirilmaz & Erol 2017; Schlüter, Diedrich & Güller 2017

AC 2: Management of forthcoming risks while accepting the companies risk situation and SC structures
Wiendahl, Slaouto & Nickel 2008; Jung, Lim & Oh 2011; Kumar, McCreary & Nottestad 2011; Leveling et al. 2014; Rotaru, Wilkin & Churilov 2014; Jordan 2015; Kilubi & Haasis 2016; Mojtahedi & Oo 2017; Schlüter, Diedrich & Güller 2017

AC 3: New potentials for proactive SCRM which result from the Digital Transformation of SCs and SCRM itself
Li et al. 2010; Goh et al. 2013; Leveling et al. 2014; He et al. 2014; Schröder, Indorf & Kersten 2014; Schlüter & Sprenger 2016; Schlüter, Diedrich & Güller 2017

AC 4: Further aspects of proactive SCRM
Grötsch, Blome & Schleper 2013; Rotaru, Wilkin & Churilov 2014; Li & Guo 2016; Park & Kim 2016; Sherwin, Medal & Lapp 2016

Figure 5: Analysis of proactive SCRM approaches

3.2.1 Proactive SCRM Approaches (RQ1)

Real-time risk monitoring and SC visualization is proposed by Goh et al. 2013 for early alert to achieve proactive SCRM. This might enable in-time knowledge regarding SC structures and dependencies but no future oriented knowledge which is required for proactive management. Leveling et al. 2014 describe data integration and Schlegel 2015 underlines the importance of immediate risk information and knowledge which can be gained by big data and predictive analytics, nonetheless a concrete description of application of analytics for proactive SCRM and inclusion in SCRM phases is not considered by found approaches.

Most publications which refer to a SCRM process describe the phases identification, assessment, mitigation and control (Ho et al. 2015). Other publications variate these phases to special requirements for proactive SCRM which contain for example a prioritization based on risk evaluation, risk criteria and the differentiation between tolerable and not acceptable risk events (Kırılmaz & Erol 2017 p. 57). Kırılmaz & Erol 2017 describes the phases of identification, measurement, evaluation, mitigation and control.

The proactive approach of Kırılmaz & Erol 2017 is based on shifting orders among suppliers and contains a quantitative model for proactive SCRM, which takes costs and risk aspects for procurement into account. Approaches for selection and combination of action measures can be found in for example Ghadge, Dani & Kalawsky 2012 p. 324.

3.2.2 Proactive SCRM Potentials Arise from Digital Transformation (RQ2)

For answering this research question lots of cross referencing and further information gathering had to be carried out. Only seven of the located publications found by the SLR referred to new technologies, Digital Transformation of SCs and risk management, data mining or predictive analytics, which shows the research need for Digital Transformation of scientific approaches for proactive SCRM. A research gap aspect is the consideration of available information, the uncertainties involved and the information integration into the SCRM procedure (Rotaru, Wilkin & Churilov 2014 p. 12, Fan et al. 2017). This future research need includes readily available, timely and accurate risk information and can be gained by application of information and communication technologies such as RFID, GPRS and social networks (Ghadge, Dani & Kalawsky 2012 p. 328, Chae 2015). The application of

Proactive SCRM Approaches

- Proactive planning
- Supplier selection
- Structural optimization of SC and dependencies
- Shifting orders among suppliers

Objectives of Proactive SCRM

- Precaution against risky suppliers
- Cost-efficiency of risk management procedures
- Minimization of damage in case a disruption occurs
- Prevention of supply delays or interruptions
- Cost-effective and time-saving mitigation

Components of Proactive SCRM

- Data integration
- Real-time monitoring
- Risk prediction
- Assessment of forthcoming risks
- Selection and combination of action measures for forthcoming risk events
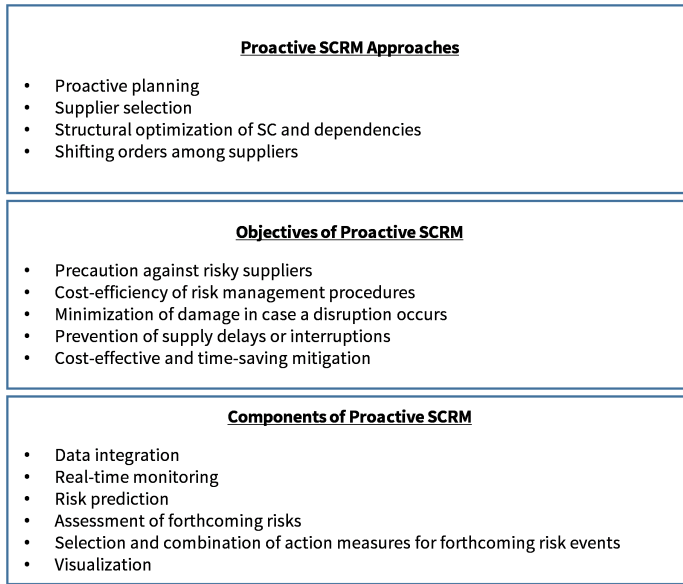- Visualization

Figure 6: SLR findings regarding proactive SCRM

big data analytics can provide SC visibility and thereby support decision making for SCRM (Seele 2017, Wang et al. 2016, Ghosh 2015, Schoenherr & Speier-Pero 2015, Leveling, Edelbrock & Otto 2014). This small number of publications refers to the application and advantages of data-driven analytical approaches in SCRM, but they rarely refer to risk management processes. The application of data mining and predictive analytics for SCRM is still a research gap. Future implications for SCRM based on digitalized approaches and digitalized approaches for conventional SCRM phases have been analyzed and summarized by Schlüter, Diedrich & Güller 2017.

3.2.3 Requirements for a Proactive SCRM Framework (RQ3)

SCRM phases are rather complex process phases which interact with each other and require a high level of technical abilities. A high number of publications describing SCRM process phases exist in scientific literature. Within this research question SCRM frameworks with characteristics for proactive management are analyzed.

Ponis & Ntalla considered 16 SCRM framework models as adequate, of which none is published after 2013 (Ponis & Ntalla 2016 p5). During the SLR of this publication there have been found 43 SCRM framework publications with a publication date of 2013 or newer, which have to be examined for requirement fulfillment to complement the SLR conducted by Ponis & Ntalla.

The framework designed by Aqlan & Lam 2015 includes risk prediction, but further description of risk prediction methods and time dependency of risk analysis are missing (Aqlan & Lam 2015).

He et al. 2015 show the potential of risk prediction, risk simulation & evaluation and risk mitigation as key process components to support the SCRM process, but a transfer to a comprehensive proactive SCRM framework and proactive SCRM procedure is still missing. The key process components are executed sequentially (He et al. 2015 p. 1008).

SCRM as part of SCM calls for technical competence and for new technological solutions to enable new SCRM approaches based on big data (Leveling et al. 2014 p. 6).

Mangla, Kumar & Kumar Barua 2014 have identified important factors for SCRM and SC sustainability. Some of these factors can be understood as requirements

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Profile of Requirements for Proactive SCRM

- Adaption of SCRM phases, to enable a future-oriented and active SCRM procedure
- Automatization and parallelization of SCRM phases instead of sequentially pass-through of SCRM phases in committees
- Orientation of proactive SCRM phases on individual forthcoming risk events (instead of for example assessment of risk categories like any natural disasters)
- Access to internal and external supply chain information
- Knowledge and transparency of SC structures and dependencies
- Knowledge and understanding about supply chain risks
- Up-to-date knowledge and in-depth information on forthcoming risks
- Quality and reliability of supply chain risk information
- Strategic risk planning
- Early identification and detection of forthcoming risks
- Assessment of forthcoming risks
- Early measure generation
- Selection and combination of optimal actions
- Uninterrupted information chain along the supply chain for risk management, which calls for collaboration among supply chain partners
- Collaborative SCRM approaches: Common proactive SCRM strategies, decision and information sharing among SC partners

Figure 7: Requirements for proactive SCRM

for proactive SCRM, inter alia knowledge and understanding about SCRs, strategic risk planning, SC integration, security issues knowledge, network and global complexion understanding, SC visibility and mutual transparency as well as decision and information sharing (Mangla, Kumar & Kumar Barua 2014 pp. 127). A research project supported by the BMWi, Germany showed the timely identification of SCR as a key issue for proactive SCRM (Cirullies & Kamphues 2014).

The profile of requirements for a proactive SCMR framework is summarized in figure 7. The requirements for proactive SCRM have been derived from existing proactive approaches and supplemented by requirements which have beforehand been raised in a workshop with SCRM research experts.
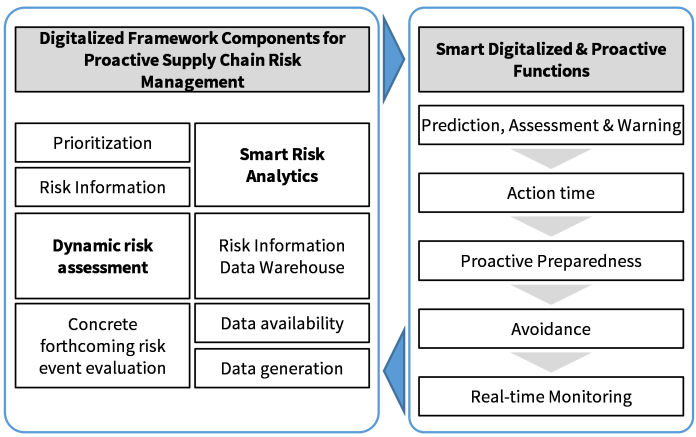
Figure 8: Digitalized SCRM components

4 Conceptual Framework

The terms approach, model, method, concept, procedure and framework are often synonymously applied for the description of a complex management approach (Vogel & Lasch 2015 pp. 102). The objective of this section is the development of a proactive management approach. Due to digitalization of SC and SCRM, the use of data, tools and analytical approaches is steadily increasing. Components for a digitalized and proactive SCRM framework are shown in figure 8.

The requirements for proactive SCRM can be fulfilled by the development of new methods for an advanced early-warning-system, which contains innovative aspects of the proactive SCRM framework, including smart risk analytics and risk prediction methods. As figure 9 shows, in addition to the early warning system an adaption of SCRM phases for management of future risks in a proactive procedure is developed.

The risk identification phase and risk assessment phase should be connected in a single comprehensive phase, because the identification of a risk requires knowledge regarding the risk assessment and especially risk impact for managers
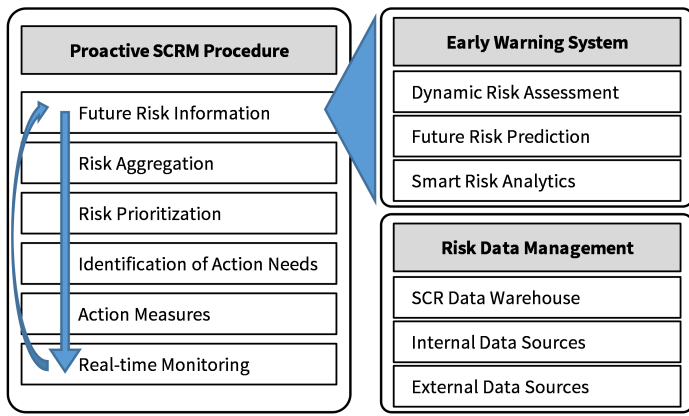
Figure 9: Digitalized proactive SCRM framework

to be able to recognize an event as a risk with a negative impact to a company or a SC network. Therefore these phases are connected in the early warning system, as can be seen in figure 9.

Risk prediction and quantitative risk assessment for future SCRs are core competences of the framework. In the following the use of data mining, big data and predictive analytics for proactive SCRM is referred to as smart risk analytics.

The collection of company and SC data from a wide range of internal and external data sources, inter alia social networks, natural disaster prediction, transportation data, stock data, material flow data and internal process and planning data, is a prerequisite for smart risk analytics. Natural disaster risks information, for example earthquakes, can be combined with industrial data and geographical data for risk sensing, assessment and predicting future events (Seele 2017 p. 684, Rajesh 2016, He et al. 2015 p. 1009, Schlegel & Trent 2015, Schlegel 2015). Smart risk analytics enables an intelligent and proactive SCRM based on the digitalization of SCs and risk management processes targets at concrete risk information for forthcoming SCR. Smart risk analytics can help assessing and managing SCR and distinguishing between risks that should be avoided and risks that should be taken (Wang et al. 2016 p. 101, p. 103). Information processing for

Financial data	Environmental data	Strategic data
Planning data	Transportation data	Real-time process data
Public Holiday	Geographic location	Product data
Production data	Communication data	Raw materials

Collaborative Risk Information Sharing among SC Partners

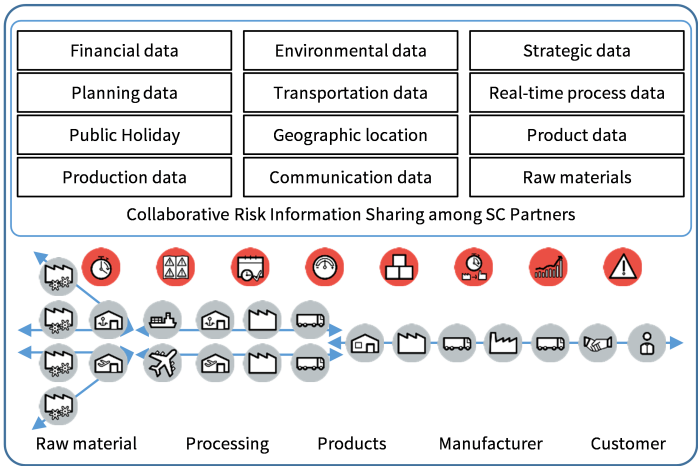Raw material   Processing   Products   Manufacturer   Customer

Figure 10: Risk information layer and data sources

SCRM, risk analysis and assessment as well as sharing of risk information should be processed proactively (Fan et al. 2017 p. 67).

For achieving smart risk analytics, the key function of the framework risk data management is needed, which leads to a high level of risk information and knowledge. Collected data has to be stored, made available and maintained in real-time to achieve potentials of SC digitalization. This enables a rapid analysis of information streams to generate real-time risk information and by application of predictive analytics risk forecasting abilities.

According to the information layer of the described Supply Chain Shadow, developed by Henke 2017, a risk information layer is described in figure 10. A variety of internal and external data sources have to be integrated in risk data management.

There is also need for research regarding the evaluation and further development of risk assessment, inter alia based on multi-criteria evaluation methods (Rotaru, Wilkin & Churilov 2014 p. 12). The extended functions of an adapted procedure

Extended Functions of Adapted SCRM Procedure Phases

Phase 0: Risk Data Management
- Storage and provision of internal, external and environmental data

Phase 1: Early Warning System: Risk Prediction & Dynamic Risk Assessment
- Future-oriented smart risk analytics

Phase 2: Risk Propagation & Aggregation
- Consideration of risk interdependencies and time-dependent propagation

Phase 3: Risk Prioritization
- Evaluation of significance of aggregated risks

Phase 4: Identification of Action Needs
- Selection of risks with further need for action

Phase 5: Optimized Combination of Action Measures
- Analysis of optimal combined actions against the forthcoming risks

Phase 6: Real-time Monitoring
- Adaption of real-time monitoring for predicted forthcoming risks
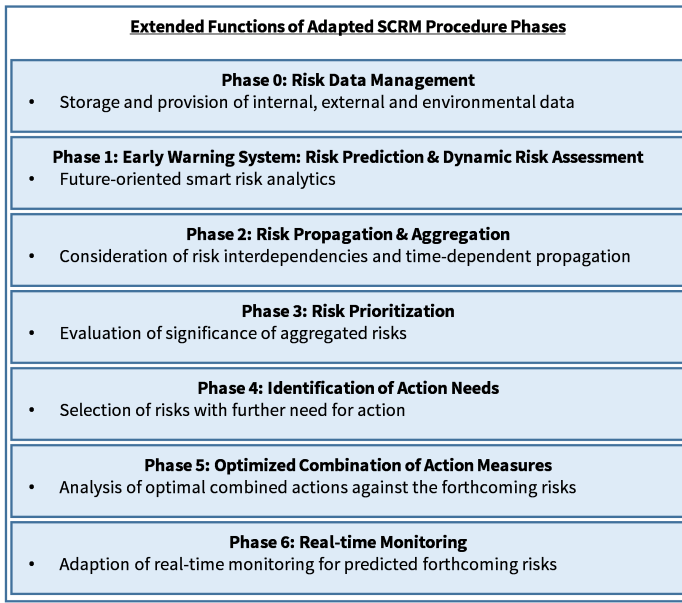
Figure 11: Adapted SCRM Phases

are core competencies of the framework, as can be seen in figure 9, and are further described in figure 11. The functions are based on SLR findings and completed with companies requirements in practice and own developed approaches. Especially the risk assessment phase has to be processed beforehand and thereby ex ante to risk events. This phase enables the triggering of the following proactive procedure.

Rapid risk assessment can be achieved by development of appropriate tool solutions (Aqlan 2016 pp. 110). Approaches of quantitative risk assessment can be found in Fahimnia 2015 and Dong & Cooper 2016. The forward-looking method is a key function for proactive SCRM procedure, hereafter referred to as dynamic risk

assessment. The method of an ex ante risk assessment is based on knowledge and information of forthcoming SCR.

Risk events are linked to SC processes and performance, which themselves can trigger further risk events and decrease the SC performance. Besides this, simultaneous occurring events can increase or diminish the probability and impact. The dynamic time-dependent risk behavior, risk interdependencies and the propagation of SCR along the entire SC has to be considered for risk assessment and proactive approaches. This research field is relatively unexplored, but first approaches can be found in for example Ghadge, Dani & Kalawsky 2012 p. 329 and Qazi, Quigley & Dickson 2015 p. 7.

Further research is required to include risks which do not occur frequently and for which no historical data is available. The methodical approach of risk aggregation should also take risk propagation along the SC into account. Depending on the risk propagation along the SC an individual risk measure for the SC partner as a viewing point has to be aggregated.

The combination of smart risk analytics and dynamic risk assessment enables a smart forward looking risk action and is the functionality of the described early warning system component of the proactive SCRM framework. It can be inferred from this, that the potential of proactive management and the ability to generate action time before a risk event occurs is enabled by the combination of existing SCRM methods, the adaption of SCRM phases and the development of time-depending and forward-looking innovative methods.

The prioritization of risks is needed by risk managers to detect the most urgent need for action and to focus on these risks (Aqlan & Lam 2015 p. 55), and thereby should be part of a proactive SCRM system. Those risks should be high prioritized, which are most likely to stop or disturb the production, and those risks which might lead to high financial losses for the manufacturing company. However, in order to evaluate the whole dimension of forthcoming risks, the risk prioritization requires the consideration of risk interdependencies and risk aggregation as described above.

For proactive SCRM approaches, the prioritization has to be linked to information which gives deeper insights into the risk sources, remaining action time and potential measures to handle the risk events. Companies need reliable information to choose which risk should be handled with cost-intensive proactive measures. A visualization approach shows identified risks with need for proactive action in a

risk heatmap (Singh & Wahid 2014 p. 64), which needs to be further developed to include dynamic time dependent information.

5 Conclusion and Discussion

The methodical approach of this paper ensures a reproducible compilation of scientific research and publications of the research fields of proactive SCRM and SCRM frameworks. For further improvement empirical validation in companies practice is still pending. The main limitations of the SLR result from used databases and keywords. This SLR includes only publications with respect to proactive SCRM approaches. Access to scientific publications is often limited. For this paper the access to SCOPUS.COM via university license was used and enabled access to many publications. Nonetheless a few publications were not available in digital form or not accessible. Open Access is a rather new and slowly spreading way to ensure access to scientific publications.

The major findings of this paper are an overview of existing approaches in the field of proactive SCRM and digitalization, comprehensive requirements for proactive SCRM as well as the development of a digitalized proactive SCRM framework. Individual risk prediction, defined as smart risk analytics, and time depending risk assessment, defined as dynamic ex ante risk assessment, are key components of this proactive SCRM framework. These components are enabled by the Digital Transformation of SCs.

Risk mitigation through collaboration has a high need for implementation (Ghadge, Dani & Kalawsky 2012 p. 328). The need for collaborative approaches of SC partners regarding collaborative decision making and strategies is high due to multiple dependencies and the risk propagation along the entire SC, which has to be initiated by management. Besides this, companies are reluctant to implement proactive SCRM processes because as Repenning & Sterman 2001 stated "nobody ever gets credit for fixing problems that never happened" (Tang 2006 p. 480). Moreover the key function of SCR prioritization has to be implemented - otherwise critical risks would simply be drowned by the flood of predicted risk events and made targeted action impossible. Figure 12 shows managerial implications of this paper.

From the findings of this paper a future research need for risk prediction and forward looking risk assessment with concrete time reference can be derived.
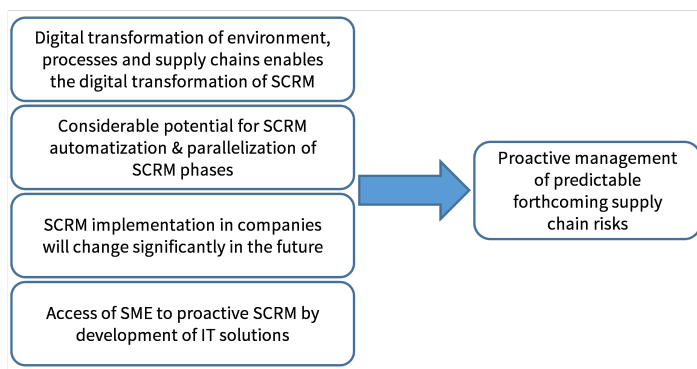
Figure 12: Significance of Digital Transformation and future research directions of SCRM

Both research gaps are correlated to higher information integration into the SCRM process. The high level information integration enables an objective and specific assessment of potential forthcoming risks. Furthermore research needs result from the limitations of the conducted SLR, so that smart risk analytics and early warning are further fields of research which have not been exploited with this analysis. Future research should be focused on risk assessment of forthcoming risks, smart risk analytics and early warning.

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