Advanced Studies in Supply Management

Christoph Bode
Ronald Bogaschewsky
Michael Eßig
Rainer Lasch
Wolfgang Stölzle *Hrsg.*

Supply Management Research

Aktuelle Forschungsergebnisse 2021

BME verband
Bundesverband Materialwirtschaft, Einkauf und Logistik e.V.

Springer Gabler

Advanced Studies in Supply Management

Reihe herausgegeben von

Bundesverband Materialwirtschaft, Einkauf und Logistik, Frankfurt, Deutschland

Weitere Bände in der Reihe http://www.springer.com/series/12204

Christoph Bode · Ronald Bogaschewsky ·
Michael Eßig · Rainer Lasch · Wolfgang Stölzle
(Hrsg.)

Supply Management Research

Aktuelle Forschungsergebnisse 2021

Springer Gabler

Hrsg.
Christoph Bode
Universität Mannheim
Mannheim, Deutschland

Ronald Bogaschewsky
Universität Würzburg
Würzburg, Deutschland

Michael Eßig
Universität der Bundeswehr München
Neubiberg, Deutschland

Rainer Lasch
Technische Universität Dresden
Dresden, Deutschland

Wolfgang Stölzle
Universität St. Gallen
St. Gallen, Schweiz

ISSN 2626-2150 ISSN 2626-2169 (electronic)
Advanced Studies in Supply Management
ISBN 978-3-658-35448-0 ISBN 978-3-658-35449-7 (eBook)
https://doi.org/10.1007/978-3-658-35449-7

Die Deutsche Nationalbibliothek verzeichnet diese Publikation in der Deutschen Nationalbiblio-grafie; detaillierte bibliografische Daten sind im Internet über http://dnb.d-nb.de abrufbar.

Planung/Lektorat: Susanne Kramer
Redaktion: Prof. Dr. Christoph Bode, Prof. Dr. Ronald Bogaschewsky, Prof. Dr. Michael Eßig, Prof. Dr. Rainer Lasch, Prof. Dr. Wolfgang Stölzle, Bianka Blankenberg
Springer Gabler ist ein Imprint der eingetragenen Gesellschaft Springer Fachmedien Wiesbaden GmbH und ist ein Teil von Springer Nature.
Die Anschrift der Gesellschaft ist: Abraham-Lincoln-Str. 46, 65189 Wiesbaden, Germany

Geleitwort

Der Bundesverband Materialwirtschaft Einkauf und Logistik e.V. (BME) fördert seit vielen Jahren den konstruktiven, offenen Austausch zwischen Praktikern und Wissenschaftlern. Dabei unterstützt der Verband aktiv das Aufspüren von Trends und Innovationen, das Erarbeiten von Erfolgsansätzen, das Vermitteln von Erprobtem und das Vernetzen interessierter Menschen und ihrer Ideen. Für seine Mitglieder und eine breite Fachöffentlichkeit bietet der BME exzellente Networking-Plattformen zum Know-how-Transfer.

Eine wichtige Säule der Verbandsarbeit ist die wissenschaftliche Auseinandersetzung mit den Themen Beschaffung und Logistik, verbunden mit der Unterstützung des wissenschaftlichen Nachwuchses. Dabei werden der Öffentlichkeit interessante Ansätze in der Forschung zum Thema Supply Management vorgestellt. Seit 1988 werden Verfasser von Habilitationen und Dissertationen mit dem BME-Wissenschaftspreis ausgezeichnet. Herausragende Studienabschlussarbeiten prämiert der BME seit 18 Jahren mit dem BME-Hochschulpreis für Beschaffung und Logistik.

In der Buchreihe „Advanced Studies in Supply Management" veröffentlicht der Verband wichtige wissenschaftliche Erkenntnisse rund um aktuelle und vieldiskutierte Managementmethoden. Auch der 14. Band zeigt Lösungsansätze für aktuelle Herausforderungen auf. Beispiele dafür sind die Beiträge zu Ansätzen zur Digitalisierung im Einkauf, zur Transparenz in Supply-Chain-Netzwerken, zu Anwendungsmöglichkeiten von Process Mining am Beispiel eines Purchase-to-Pay-Prozesses für Raw Materials und zur Nachhaltigkeit in der Bekleidungsindustrie.

Mein herzlicher Dank gilt den Autoren für ihre Beiträge sowie insbesondere den Professoren Christoph Bode, Ronald Bogaschewsky, Michael Eßig, Rainer Lasch und Wolfgang Stölzle für ihre fachliche Unterstützung und ihr großes Engagement.

Eschborn, im Juni 2021

Gundula Ullah
Vorsitzende des Vorstandes
Bundesverband Materialwirtschaft, Einkauf und Logistik e.V.

Vorwort

In dem vorliegenden 14. Band der Reihe „Advanced Studies in Supply Management" werden erneut ausgewählte wissenschaftliche Fortschritte in diesem Forschungsfeld dargestellt. Er ist zugleich Tagungsband des 14. Wissenschaftlichen Symposiums „Supply Management", das im März 2021 aufgrund der Corona-Pandemie digital stattfand. Veranstalter dieser Tagung ist der Bundesverband Materialwirtschaft, Einkauf und Logistik e.V. (BME), der auch als Herausgeber der Buchreihe fungiert. Inhaltlich verantwortlich für die Durchführung des Wissenschaftlichen Symposiums und der daraus resultierenden Schriften ist der Wissenschaftliche Beirat des Bundesvorstandes des BME.

Die außerordentlich große Bedeutung des gesamten Beschaffungsbereichs spiegelt sich in der seit Jahren deutlich ansteigenden Anzahl wissenschaftlicher Publikationen und anwendungsnaher Arbeiten wider. Das Wissenschaftliche Symposium „Supply Management" hat sich zu einer zentralen Plattform für die Präsentation von sowie den Austausch über neueste Forschungsergebnisse aus den Gebieten Einkauf, Material-management, Logistik und Supply Chain Management etabliert.

Die in diesem Band veröffentlichten Beiträge wurden gemäß dieser beiden Tracks auf dem Symposium in strenger wissenschaftliche sowie stärker anwendungsorientierte Arbeiten unterschieden. Alle Einreichungen sind in einem Double-Blind-Review-Verfahren von unabhängigen Gutachtern eingehend geprüft worden. Diesen gilt unser besonderer Dank für die gewissenhafte Erstellung der Gutachten und die dort angeführten Verbesserungsvorschläge für die Beiträge. Aufgenommen wurden zudem die Arbeiten, die sich für das Vortragsfinale des BME-Wissenschaftspreises 2021 qualifizieren konnten. Der Jury des BME-Wissenschaftspreises gilt ebenfalls unser Dank für die geleisteten Begutachtungen.

Der vorliegende Band zeigt die große Breite und Tiefe der wissenschaftlichen und anwendungsnahen Arbeiten im Bereich Supply Management auf. Es ist dem Wissenschaftlichen Beirat und dem BME ein besonderes Anliegen, Forschungen in diesem Bereich weiterhin intensiv zu fördern.

Eschborn, im Juni 2021

Prof. Dr. Christoph Bode, Mannheim
Prof. Dr. Ronald Bogaschewsky, Würzburg
Prof. Dr. Michael Eßig, München
Prof. Dr. Rainer Lasch, Dresden
Prof. Dr. Wolfgang Stölzle, St. Gallen

Inhaltsverzeichnis

Teil B Anwendungsorientierte Forschungsbeiträge

Transport drones in production logistics: Is there a use case?
Stephan L. K. Freichel, Christoph S. Zoller, Johannes K. Wörtge, Wladimir Rempel

Digital supplier integration – Transaction 4.0 in buyer-supplier relationships
Markus Burger, Julia Arlinghaus

Managing the supply side of digital platforms: framework, categorization and selection of complementors for industrial IoT and financial services platforms
Wolfgang Buchholz, Holger de Bie

Empirical studies of proposing KPIs for corporate procurement and its strategic suppliers to steer and control sustainable procurement practices
Elisabeth Fröhlich, Lisa Nießen

Sustainability Governance – Nachhaltigkeit in der Bekleidungsindustrie
Jakob Keller, Kristin Laub, Rainer Lasch

Teil A

Wissenschaftliche Forschungsbeiträge

The paradigm shift of supply chain management: risks, technological innovation and social impact

Hendrik Birkel

Abstract

Technological change, as well as global disruptions such as pandemics, natural disasters, or trade wars, are causing increasing challenges to companies, policymakers, and society and impact the flow and management of goods in today's global value networks. This dissertation investigates these challenges and risks due to the disruptive change through Industry 4.0, its management as well as economic, environmental, and social implications on supply chain management. The examination of supply chain risk management and the impact of the adoption of the Internet of Things, its influence on transparency, risk strategies and competitive advantage provides further value-added. The application of systematic literature reviews, theory-based case study research, and machine learning supported bibliometric and network analyses create a holistic review of existing literature, the identification of core aspects and research gaps. Furthermore, the results support decision-makers in coping with uncertainties and enable the development of strategic and operational as well as technical and social capabilities to ensure superior performance.

1 Introduction

The digital transformation is fundamentally changing the way a company is managed, how it cooperates with partners and competitors, and how entire value networks are structured. In contrast to incremental steps of sustainable technologies, disruptive technologies offer novel and more efficient opportunities with the possibility for a rapid progression (Bower and Christensen, 1995; Christensen, 1997). The influences of the fourth industrial revolution (Industry 4.0) encompass this progress and aim at the creation of fully digitized, intelligent, and decentralized value networks (Kagermann et al., 2013). The potentials of implementation are numerous and range from a real-time transfer of data to the elimination of monotonous and repetitive tasks (Ben-Daya et al., 2019;

C. Bode et al. (Hrsg.), *Supply Management Research*, Advanced Studies in Supply Management, https://doi.org/10.1007/978-3-658-35449-7_1

Birkel et al., 2019). The applications in the field of supply chain management (SCM) are particularly exciting, as technologies, such as the Internet of Things (IoT), enable end-to-end transparency of goods, processes, and work steps that were previously not possible (Ben-Daya et al., 2019). However, the implementation also inherits risks while leading to extensive changes for individuals, companies, and entire industries (Hofmann and Rüsch, 2017; Ivanov et al., 2019). This is also evident from the latest Allianz Risk Barometer, ranking the risk of cyber incidents, such as data breaches, information technology (IT) failure or outage, cybercrime as well as fines and penalties, in first place for the first time (Allianz Global Corporate & Specialty SE, 2020). This reflects the challenges companies face in dealing with disruptive change and their struggle to overcome the risks. Despite their importance, risks of Industry 4.0 have received comparatively little attention from scholars while potentials are comprehensively investigated (Rosa et al., 2020; e.g. Xu et al., 2018).

Besides, the enduring Covid-19 pandemic caused unprecedented disruption to almost every industry and business and demonstrated the vulnerability of today's value networks. The sales volume of the world's 17 largest car companies, for example, dropped by 41% (Ernst & Young, 2020) and was accompanied by dramatic losses in transport capacity in the sea and air freight sectors, which negatively impacted further supply chains. Thus, the global interconnectedness of companies, favored by the spread of information and communication technologies itself, became particularly evident. In addition, further developments pressure supply chains, such as the demand of customers for a broader spectrum of products with a higher degree of individualization, short delivery times, and high service at low costs (Christopher, 2016). This highlights the requirement for a holistic, multi-level supply chain risk management (SCRM), to reduce vulnerabilities and ensure business continuity (Fan and Stevenson, 2018; Goh et al., 2007; Jüttner, 2005; Wieland and Wallenburg, 2012). The application of Industry 4.0, especially IoT inherits the potential for tackling disruptions within SCRM since e.g. operational processes can be improved while costs are reduced (Zhou et al., 2015).

Therefore, the motivation of this work is to address the essential problems in the area of Industry 4.0 and SCRM that companies are facing worldwide while closing current research gaps. To overcome the challenges and risks of Industry 4.0 a holistic examination was performed, to determine the effects on economic, ecological, and social aspects and to develop a guideline with instructions on how to deal with these disruptive issues. In addition, the work provides the foundation for a joint discussion between society, research, business, and politics. Regarding SCRM, the central question of how risks can be dealt with in the future and how Industry 4.0 enriches the process steps of SCRM, the internal and external pathway as well as the effects on SCMR outcome are addressed from the perspective of a single company as well as the entire value chain. For companies, this allows insights into the latest structures of IoT systems, primary use cases, and potential implications for their own processes. Furthermore, the field of SCRM is disclosed through machine-learning supported bibliometric and network analyses to structure and facilitate access to the research field and motivate further research endeavors.

2 Structure of research objectives

In the following, the structure of this work is presented, which is divided into four parts. Each part represents a paper with a specific motivation, approach, and objective of the dissertation. This segmentation allows for publication in reputable journals, which has already been accomplished for the majority of the papers. All papers are located in the research fields of Industry 4.0 and SCRM. **Figure 1** illustrates the respective focus of each part as well as their overall coherence.

Within the first part, the question of *which risks* companies have to tackle in connection with the development of Industry 4.0 is answered. For this purpose, a comprehensive risk framework is developed with the help of a holistic analysis of the literature as well as expert interviews with companies of various sizes and sectors. To ensure a balanced view of people, planet, and profit and to facilitate long-term sustainable development, the work is enhanced by the perspective of the Triple Bottom Line. The results reveal a wide variety of aspects that can be divided into economic, ecological, social, political, and legal as well as technical and information technology implications.

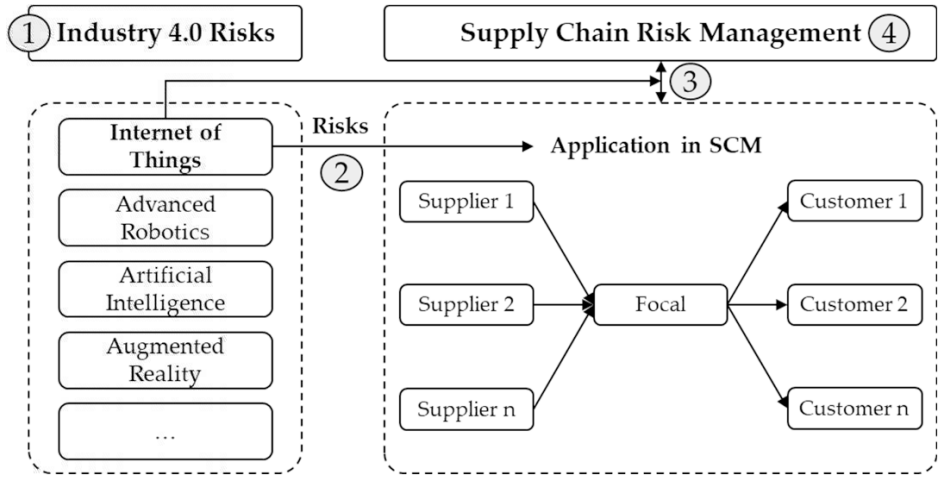
Complementary to Part 1, Part 2 deepens the consideration of challenges and risks through Industry 4.0, focusing on IoT and SCM. This is due to several reasons: first, IoT differentiates itself from other Industry 4.0 related technologies such as Additive Manufacturing, Advanced Robotics, or Augmented Reality through the creation of a digital network of physical objects and the possibility to globally collect information in real-time without human interaction. Especially for SCM, the network consideration and data collection across different supply chain tiers are of particular relevance. This is also illustrated by the potentials such as improved visibility in the supply chain (Verdouw et al., 2016) as well as improved quality standards and reduced waste (Dada and Thiesse, 2008; Harris et al., 2015). In line with Part 1, potentials can only be realized after the risks have been addressed. For this reason, Part 2 uses a systematic literature review to examine 102 papers to analyze the challenges and risks of IoT for SCM.

Part 3 draws on the findings of the second part and relates the potential of IoT to SCRM. Its importance has been highlighted in particular by the global Covid-19 pandemic and illustrates the significance of agile and efficient risk management to maintain value chains worldwide. IoT offers the possibility to capture information such as positions, temperatures, or shocks of goods and causes a fundamental change in information availability and processing (Miorandi et al., 2012), which in turn affects the management of risks in supply chains. Therefore, Part 3 uses Information Processing Theory as a theoretical foundation to examine the impact of IoT on SCRM. This includes in particular the impact on the risk process, the internal and external pathway as well as the impact on the SCRM outcomes. The research endeavor is performed using a multiple case study including primary and secondary data. The results demonstrate the positive effects on process management and data availability, process velocity, and transparency. At the same time, employees are affected, as the task profile changes due to changing processes

and risk strategies. In addition, technological alignment intensifies relationships with business partners resulting in a changed interaction and adapted forms of cooperation.

In addition to the boost of the literature from the Covid-19 pandemic, the steady growth of the topic of SCRM has led to a high degree of fragmentation (Fan and Stevenson, 2018). This is illustrated by different definitions and concepts or, in turn, synonymous usage. Part 4 addresses this research gap and thus picks up the findings of Part 3 since the SCRM process can be seen as a fundamental consensus across the field. Using machine-learning supported bibliometric and network analyses, 586 publications were examined to develop a structured overview of the SCRM domain. To expand the literature analyses such as affiliation statistics, automated keyword analyses as well as PageRank and co-citation were used. This allows to cluster current research, facilitates access for new researchers, and to identify research gaps.

Figure 1: *Structure of research objectives*



2.1 Part 1: Risk framework for Industry 4.0 within the context of sustainability[1]

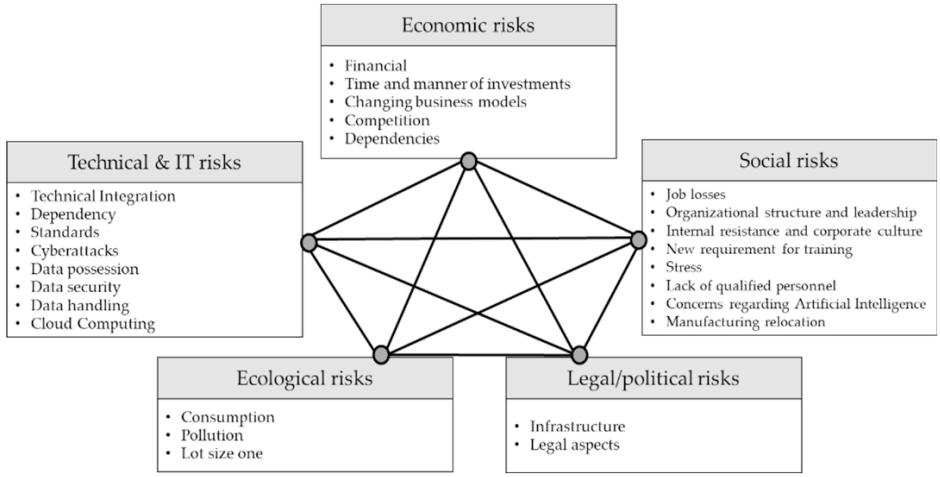
The profound transformation of value creation in the context of the fourth industrial revolution has been a continuously evolving topic since its introduction at the Hannover Fair 2011 (Xu et al., 2018). The multitude of Industry 4.0-related technologies, their interconnection, and the tremendous potential drive changes to almost every business

1 This part is published in Birkel et al. (2019).

area of a company. The initial excitement of the numerous advantages pushed the scientific literature, while within companies only a few pilot projects were implemented (Birkel et al., 2019). One reason is that companies face the challenges of a cost-intensive implementation with a simultaneously insufficient level of knowledge, which hampers the realization, especially in the case of small companies (Yan, 2017). In addition, there are competing target demands from partners, politics, and society, which additionally call for more sustainable development (Kiel et al., 2017).

This results in a highly divided situation of a potential-driven and fragmented literature of different disciplines focusing on diverse technologies with a low implementation level of overwhelmed companies. To tackle this issue, a comprehensive analysis of Industry 4.0 risks was performed. Thus, the question of *which* risks arise through the implementation of Industry 4.0-related technologies is answered. By applying a qualitative empirical research design based on interviews with 14 experts and the enrichment with the current state of the literature, a deep but comprehensive analysis was achieved. This is particularly suitable for complex phenomena (Yin, 2018), such as Industry 4.0. Thereby, special emphasis was placed on the acquisition of small and medium-sized companies for which the risks differed greatly. A total of 239 sub codes were derived from the interviews for the analysis, which were gradually transformed into top codes, and the five dimensions of the risk framework (see **Figure 2**).

Figure 2: *Industry 4.0 sustainable risk framework (Birkel et al., 2019)*



The findings uncover the high diversity of risks in and across the dimensions. These range from high financial requirements and employee anxiety to a lack of political infrastructure. The highest proportion of mentions is found in the economic dimension,

in which monetary expenses with unclear amortization are a key issue. The decision to initiate an investment under uncertainty is impeded by the high complexity of the interdependencies and the lack of measurability. At the same time, the implementation of Industry 4.0-related technologies often requires a strong customer orientation with intensified interaction with supply chain partners. This, in turn, can lead to changing requirements e.g. adjustments in the business model or the adaptation of risk management. Especially for small and medium-sized companies, platform-oriented thinking in strategic alliances can be advantageous.

Despite the general ecological influences, the consideration of these issues remains a subordinate topic for companies, regardless of the long-term implications, such as the mining finite resources or the generation of waste. From a customer perspective, the responsibility for compliance and verification is attributed specifically to large focal companies (Hartmann and Moeller, 2014). However, their compliance and verification of sustainable standards in supply chains are often limited to direct suppliers neglecting lower-tier suppliers (Pagell et al., 2010). Furthermore, the interview partners assigned the social dimension great importance, which includes aspects such as fear of technological change and job losses as well as new work requirements. In this context, the collaboration between politics, associations, and the top management of companies plays a crucial role, as employees need to be provided with long-term security while also technological regulations, standards, and infrastructure have to be established. It is the only way to address technological and IT-related risks.

This reflects that along with a multitude of potentials, there are still numerous risks to overcome. Therefore, Part 1 provides an important comprehensive yet in-depth analysis and reconciles the current state of the industry with scientific research. This provides valuable recommendations for handling Industry 4.0-related risks as well as a joint basis for discussion between policy-makers, companies, researchers, and society. It also offers an important theoretical contribution as an impulse for further research projects in the area of Industry 4.0 and lies the foundation for detailed analyses of specific Industry 4.0-related technologies.

2.2 Part 2: Challenges and risks of the Internet of Things for supply chain management[2]

While in Part 1 the risks of Industry 4.0 were broadly discussed, in this part challenges and risks of IoT are synthesized. This focus was chosen to provide in-depth insights into specific technology clusters of IoT and its implications for SCM. Due to the evolution of value creation towards globally distributed value networks, the impact of IoT is particularly highly valued due to its definition as a "[...] network of physical objects that are digitally connected to sense, monitor and interact within a company and between

2 This part is published in Birkel and Hartmann (2019).

the company and its supply chain [...]" (Ben-Daya et al., 2019, p. 4721). Therefore, it supports the core aspects of SCM, such as connectivity, communication, and exchange of information within and across company boundaries. At the same time, the focus on IoT and SCM allows greater emphasis to be placed on relational aspects between companies, which is indispensable for the end-to-end implementation of Industry 4.0.

Part 2 examines the impact of challenges and risks of IoT on SCM by answering the following sub-questions: how can the literature be *classified*, how will challenges and risks *influence* supply chains in the future and how can they be *overcome*. The distinction between 'challenges' and 'risks' was chosen to illustrate the importance of the temporal dimension. On the one hand, challenges address the negative impact that arises before the implementation of IoT such as concerns or barriers. Risks, on the other hand, consider the negative influences on customers, the organization, and its environment after implementation. The findings are derived from a systematic literature review of 102 papers based on the five-step guideline from Denyer and Tranfield (2009). In addition to the descriptive analysis, by applying a two-dimensional content analysis approach, the papers are subdivided into environmental, network-related, and organizational levels, inspired by Jüttner et al. (2003), as well as a temporal dimension (see **Table 1**). To further generate insights, the findings were synthesized to identify relations between individual topics.

The findings emphasize the major obstacles of *challenges*, as two-thirds are assigned to this dimension. Technological challenges, such as security issues or hardware and software limitations, are particularly striking. In addition, the strong interdisciplinary relation to the field of IT becomes apparent, which is expressed in the intensive use of the methodology 'design science'. Furthermore, the technological dimension exhibits intensive relations to all other topics, which is why it can be identified as the core dimension of IoT and SCM. Overall, the lack of technical, organizational, cultural, and regulatory harmonization leads to rising supply network challenges, which e.g. hamper the realization of unified end-to-end solutions (Dutton, 2014). Beyond the identification of challenges and their relations, the results reveal insights about potential solutions, such as the application of blockchain and the need to generate income-centric values beyond traceability-centric values (Pang et al., 2015).

The majority of *risks* are also identified in the technological area, especially in form of attack-related risks, which can be seen as a direct impact of security issues. However, similar to challenges, risks are manifold and ranges from aspects such as data leakage to the physical injury of employees. Another frequently mentioned issue is the network-related dimension, which addresses the dichotomy of data sharing and asymmetric information resulting in possible opportunistic behavior. This is paramount as IoT massively amplifies these risks while personal relationships and trust continue to take on an increasingly important role in the digital world. This is emphasized by the intensive relation of these risks to other areas. In addition, to guide the implementation of IoT, the results are extended to a conceptual model for future research on IoT adoption.

Due to the comprehensive consideration of challenges and risks, the results of this study also contribute to the extension of existing literature. Complementing the theoretical insights, the practical contribution is highlighted, calling for inferences on changing structures of supply networks and risk management, the need for new collaborations, and adaptive trust management. In addition, the actions and utilization of pioneers of IoT implementation, such as the food supply chain, are synthesized, which serve as a guide and orientation for other companies.

Table 1: *Framework of IoT challenges and risks for SCM (Birkel and Hartmann, 2019)*

Level of analysis		Challenges	Risks
Environmental	*Economic*	high costs	creation of zero-sum competition
		business model adaptation	further economic risks
		unknown profitability	
	Social	privacy concerns	uncertain technology adoption
		further social challenges	surveillance and distrust
			further social risks
	Techno-logical	security issues	attack-related risks
		lack of standards & interoperability	low data quality
		hardware limitations	further technological risks
		software limitations	
	Political	lack of legal regulations	generic political risks
Network-related	*Relational*	trust issues	asymmetry of information
		complex network implementation	distrust & trust management
		high collaboration & data exchange	complex network coordination
		supply chain reconfiguration	dependencies & consequences
			opportunism
			competition
Organizational	*Internal*	lack of knowledge	complex data management
		complex system implementation	strategic management
		organizational changes	operational management
		concerns of employees	financial-related
			human resources

2.3 Part 3: The future of managing supply chain risk through the Internet of Things[3]

While within Part 1 and Part 2 risks of Industry 4.0 were comprehensively elaborated, Part 3 focuses on the influence of IoT on risk management. Since an important research field within SCM is the management of disruptions, the connection between digital technologies and SCRM is straightforward (Ivanov et al., 2019). Especially the influence of inaccurate evaluations, misjudgments, or poor decision-making can have devastating effects on the supply chain (Chowdhury and Quaddus, 2016; Colicchia and Strozzi, 2012). Furthermore, the importance of superior decision-making in the context of disruption has been highlighted by recent developments, such as the Covid-19 pandemic (van Remko, 2020). Despite the awareness of the importance of inter-firm sharing of risk-relevant information, the cohesion of information needs and information processing capabilities has received little attention in the context of SCRM (Fan et al., 2016; Kilubi and Rogers, 2018).

For this reason, Part 3 addresses the question of *how* and *why* IoT impacts SCRM. For a holistic view, an analysis based on the framework of Fan and Stevenson (2018) was conducted. This includes 1) the risk process consisting of the identification, assessment, treatment, and monitoring stages 2) the pathways of SCRM (internal and external) and the SCRM outcomes. Information Processing Theory is used as theoretical foundation since the fit of information needs and information processing capabilities is a key element of SCRM. To answer the research question, a multiple case study design is applied, which includes 12 companies from the manufacturing industry. Special attention was paid to the acquisition of companies from both, the business-to-business as well as the business-to-customer area. The case study was conducted under strict adherence to validity and robustness criteria. For the evaluation open, axial, and selective coding according to Corbin and Strauss (1990) is used to achieve a stepwise aggregation to superior categories.

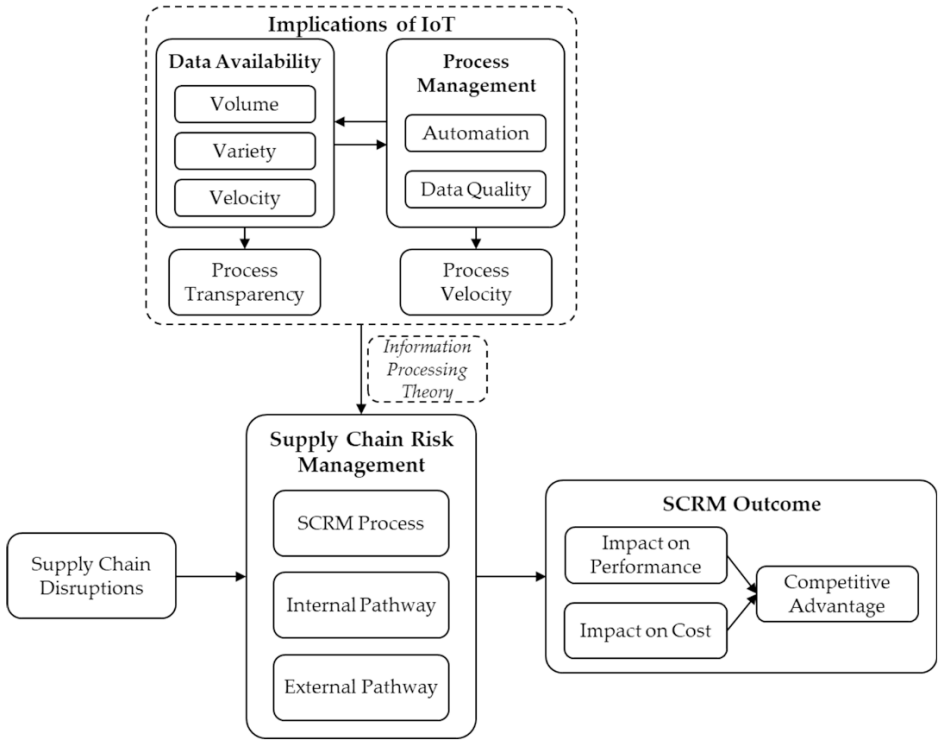
To increase the practical relevance, in the first step an overview of the structure of IoT systems is provided. For this purpose, each of the systems is broken down into its individual layers (sensing, networking, sensing, and interface layer) (Xu et al., 2014). This reveals the primary use of radio-frequency identification as a continuing important technology. In most cases, a tracker to determine GPS coordination is included. In addition, sensors are used to determine the temperature, air pressure, vibrations, and shocks. Surprisingly, the analysis of the IoT systems reveals a high degree of internal development, which is only supplemented by external expertise. For data integration, both internal and external data are used. These can be wide-ranging including data from news sites or social media, which demonstrates the easy extensibility of IoT systems.

With regard to the SCRM framework (see **Figure 3**), the implications reveal a positive impact on data availability, characterized by the 3Vs volume, variety, and velocity. This

3 This part is published in Birkel and Hartmann (2020)

enables an improvement in process transparency. At the same time, improved process management can lead to a higher degree of automation and improved data quality, and finally to a higher process velocity. With regard to the individual steps of the risk process, the implementation of IoT reveals direct and indirect positive influences. They facilitate e.g. an optimized response to micro risks, improved use of quantitative methods with intelligent data processing, and improved proactive and reactive strategies. In addition, positive relations to the internal and external pathways are derived. These comprise improved risk transparency, knowledge, and strategies. At the same time, IoT influences SCRM tasks, as smaller risks can be handled automatically without the need for an employee to approve the actions. However, the literature and interview partners stress the fact, that it will not be able to replace human judgment.

Figure 3: *Application of IoT in SCRM research framework (Birkel and Hartmann, 2020)*



Furthermore, positive relations to supplier selection and evaluation are uncovered, since profound insights into the processes of the suppliers are possible. However, this also highlights the barriers of disclosing data, which is addressed in the previous parts. SCRM outcomes can also be positively influenced, including the impact on performance

and costs. With regard to costs, for example, cost-cutting benefits can be achieved through lower inventories and reduced supplier-related costs. In combination with the enhanced performance achieved through higher process transparency and process velocity, this allows for a competitive advantage.

Thus, the case study in Part 3 addresses several important aspects in the area of technology-enhanced SCRM based on a strong theoretical foundation. At the same time, the disclosure of social issues among employees and partners as well as in the area of risk monitoring motivates further studies.

2.4 Part 4: Supply chain risk management through a bibliometric and network lens

Even though the elaborations on SCRM in Part 3 broaden the existing literature, it remains fragmented. Therefore, this part aims to synthesis the literature in the field of SCRM, and at the same time searches for methodological advancement. The following research questions can be formulated: 1) What is the *current status* of the literature on SCRM including its associated process and how has it evolved? 2) Which specific *research clusters* can be identified? For this purpose, a bibliometric analysis was applied, which is a powerful tool for analyzing established and emerging topical areas (Fahimnia et al., 2015a) and allows the disclosure of versatile conclusions, such as cooperation and networks between authors, institutions, or regions as well as patterns in keywords and research streams (Geng et al., 2017; Wu et al., 2018). Thus, this quantitative approach represents a transparent and objective research methodology alongside conventional literature analysis (Fahimnia et al., 2015b). To enhance the traditional identification of research clusters through a manual review of papers, an analysis using topic modeling was conducted with the help of the machine-learning software Python. This additionally fosters reliability and reproducibility.

For the analysis of the field of SCRM, 586 papers were examined. These were identified using an optimized search with a combination of synonyms of the keywords 'supply chain' as well as 'risk management' and its process steps.

In a further step, they were processed using the software Bibexcel and Gephi. To conduct a content-based classification, a network analysis was performed, including a citation, a PageRank, and co-citation analysis. The topic modeling for the content analysis of the research clusters was performed using Latent Dirichlet Allocation (LDA), a generative probabilistic model (Blei et al., 2003).

First, the findings reveal the increasing development of the research field SCRM, main contributing journals (e.g. International Journal of Production Research, International Journal of Production Economics, and Supply Chain Management: An International Journal), the influence of single authors (Blackhurst J., Ivanov D., Sawik T., and Talluri S.), as well as an affiliation statistic. The latter highlights the large number of literature

from the UK, the United States, and China as well as the close global collaboration of the research teams. Furthermore, for the keyword analysis, 3,720 codes were analyzed and clustered, which demonstrate the wide-ranging topic coverage through the conventional four process steps. Thereby, the connection of SCRM to areas such as finance, sustainability, and quality management is highlighted. By performing a citation, PageRank, and co-citation analysis, in-depth insights into the most important and influential papers are given and the preparation of research areas was enabled. They can be divided into seven clusters (see **Table 2**). The analysis of the PageRank, which assesses the prestige of a paper (Fahimnia et al., 2015a) places cluster six in the first place, which, however, is due to the small number of papers within the cluster. The analysis further reveals that the use of certain research methodologies cannot be clearly assigned to any single cluster; instead, all clusters are evenly addressed by different methodologies, primarily empirical case studies and literature reviews. This distribution is also displayed in the use of theories, which overall use is at a low level. Furthermore, it is revealed that all clusters are interrelated, but with a different intensity. Due to its generalistic view on the risk process, conceptual frameworks, and models of SCRM, Cluster 2 is in the center. Within cluster one all papers were published primarily in 2004, while cluster three concentrates thematically on the upstream supply chain. In contrast, cluster seven is the youngest cluster and specifically includes a vertical consideration of supply chains besides the horizontal view. An emerging topic in this context is the Ripple Effect, which examines the wave-like spread of risk in supply chains (Ivanov et al., 2019).

The analysis and synthesis of the entire research field of SCRM represent the value-added of this bibliometric analysis, as it offers a structured overview, increases transparency, and helps to identify thematic relations and focus areas that were not apparent before. Therefore, it facilitates access for SCRM researchers and helps to motivate further research endeavors.

Table 2: *Research topics determined by LDA and top two papers of each cluster*

Cluster research topic		**Terms** (determined by LDA & sorted by columns)		**Publications** (sorted by page rank)
1	Essential practical approaches for assessing SCRM: the beginnings	case study product design risk assessment manage risk purchase organization	identify risk assess risk risk analysis risk value risk uncertainty	e.g. Norman and MacDonald (2004), Christopher and Lee (2004)
2	Overview of SCRM: the risk process, conceptual frameworks and models of SCRM	case study risk factor risk assessment manage risk hierarchy process	decision make risk mitigation risk process risk measure type risk	e.g. Tang (2006), Hallikas et al. (2004)
3	Upstream SCRM: supplier and portfolio selection	disruption risk customer order wholesale price reliable supplier value risk	backup supplier order quantity supplier selection dual sourcing number supplier	e.g. Kleindorfer and Saad (2005), Tomlin (2006)
4	Managing supply disruptions through resilience, robustness and agility	resilience robustness literature review agility robustness risk mitigation case study	catastrophic event customer value manage risk risk exposure empirical study	e.g Christopher and Peck (2004), Craighead et al. (2007)
5	Supply chain risk classification and mitigation: different perspectives	mitigation strategy risk mitigation literature review risk mitigation strategy global chain	manage risk risk associate risk model propose model case study	e.g. Chopra and Sodhi (2004), Sodhi et al. (2012)
6	Strategies for managing supply chain risks: empirical analyses and investigations	cultural adaptation manage risk literature review cultural difference network analysis	global sourcing case study disruption risk transaction cost decision make	e.g. Thun and Hoenig (2011), Wagner and Bode (2006)
7	Consideration of structural dynamics of supply chains: a network perspective	ripple effect focal firm disruption risk production distribution network disruption	risk exposure network level disruption propagation risk chain structural relationship	e.g. Ho et al. (2015), Ivanov et al. (2017)

3 Moving further: research development and endeavors

The research work conducted offers many opportunities for further work, which I would like to address in the future together with other international researchers. Particularly exciting are the digital developments in the area of SCM and the future compatibility of ecological and ethical social values. Only by addressing these values, it will be possible to achieve a genuine human-machine interplay, which, in turn, will be necessary to respond to the changing requirements of a holistic sustainable development in the long term. For this purpose, topics such as the use of artificial intelligence in strategic organizational decision-making (Trunk et al., 2020), the use of big data analytics in integrated business planning (Schlegel et al., 2020), and the application of predictive analytics in logistics have been investigated (Birkel et al., 2020). The perspective of SCM inheres an important role since not only moral concerns of customers should be addressed but in particular the congruence of the values of employees and suppliers with, for example, strategic decisions of a firm's management (e.g. Vial, 2019). Furthermore, risk management is gaining in importance and needs to be further deepened as a crucial field of research. This includes, for example, analyses of the future use of methods and technologies as well as corresponding multi-tier structures and industries.

4 Summary and implications

Challenges within the field of SCM are manifold. Besides the digital transformation, the ongoing globalized but volatile value creation, the changing customer demands, and increasing complexity influence the way SCM has to be understood. Companies that succeed in the long term are those that embrace the digital transformation and exploit the potentials for themselves. However, these changes create risks that challenge the maintenance of value creation. For these reasons, understanding the transformation, the associated risks, and their management is indispensable. The individual parts of this dissertation deal with these multiple challenges to address the risks posed by Industry 4.0 and IoT and to investigate their impact on the management of supply chain risks. In addition to the expansion of the literature and identification of future research fields, companies are granted decision support and recommendations for action for the implementation and balance of economic, ecological, social, and technical aspects. Different research methods were used to synthesize the findings from literature and practice. These include systematic literature analyses, case study analyses, and bibliometric analyses. The respective application was specifically adapted to the research object and substantiated with theoretical foundations. For a holistic view of the research subjects in the context of the case studies, special emphasis was also placed on a balance of the fields of activity, industries, and sizes of the companies.

The results of the respective research subjects are versatile. The risks caused by Industry 4.0 and IoT each highlight the dominant technological challenges that companies have to deal with. In particular, technical integration, lack of standards, dependencies, fear of cyberattacks, and data sovereignty pose serious difficulties. The need for high investments as well as the unclear amortization hampers the implementation within companies. This circumstance is exacerbated by the difficulty of quantifying explicit values. For this purpose, a conceptual model for the adoption of IoT is developed, which incorporates the 'perceived usefulness' and 'perceived ease of use' and shall motivate further contributions. Last but not least, additional social factors are involved, which are expressed in the employees' fear of change and the vague relationship between job losses and newly created jobs as well as the required level of qualification.

The consideration of risks from a supply chain perspective provides further important insights. Industry 4.0 may not only require changes to a company's business model but also changes human interaction across company boundaries. Of particular interest is the transformation of the value of trust and how trust can be developed in the context of increasing digitalization. At the same time, by distinguishing challenges and risks, a distinction could be made between issues that actually arise through the implementation of the technology and prior obstacles that companies face. The focus on challenges reveals the novelty of the research field and the scarcity of practical applications.

The investigation of the technologies and their influence on the SCRM process, internal as well as external pathways is achieved. In particular, the added value of utilizing an IoT system is demonstrated and insights into the structure and development are provided. The improvements range from higher transparency and process velocity to increased performance, lower costs, and the creation of competitive advantages. Further implications arise for collaboration with suppliers. Through improved audits and in-depth insights into supplier operations practically mirrored the risks discussed earlier. Improvements are also identified with regard to the internal pathway, more specifically employees and risk strategies. The breadth of the research field and the high degree of fragmentation of the field of SCRM becomes apparent. This circumstance was addressed with a bibliometric analysis. This allowed, among other things, insights into research focus, author networks, the quantification of the influence of papers, and the development of the research field.

The synthesis of the research results highlights the multifaceted implications of the work. In addition to providing practical support as well as a theoretical contribution, the overall purpose is to encourage further research endeavors. Opportunities for this can be identified both in the consideration of technological change, SCRM, and at its interfaces. Through further studies and the realization of additional use cases, a greater understanding can be developed to accompany technological change step by step. The significance of this research field, besides the fundamental importance of technological change and risk management in SCM, became particularly evident through the Covid-19 pandemic.

References

Allianz Global Corporate & Specialty SE (2020): Allianz Risk Barometer – Identifying the major business risks for 2020.

Ben-Daya, M.; Hassini, E.; Bahroun, Z. (2019): Internet of things and supply chain management: a literature review. In: International Journal of Production Research, 57 (15–16), pp. 4719–4742.

Birkel, H.; Kopyto, M.; Lutz, C. (2020): Challenges of Applying Predictive Analytics in Transport Logistics. In: Proceedings of the 2020 on Computers and People Research Conference (SIGMIS-CPR '20: 2020 Computers and People Research Conference), 2020, Nuremberg Germany.

Birkel, H.; Veile, J.; Müller, J.; Hartmann, E.; Voigt, K.-I. (2019): Development of a Risk Framework for Industry 4.0 in the Context of Sustainability for Established Manufacturers. In: Sustainability, 11 (2), p. 384.

Birkel, H. S.; Hartmann, E. (2019): Impact of IoT challenges and risks for SCM. In: Supply Chain Management: An International Journal, 24 (1), pp. 39–61.

Birkel, H. S.; Hartmann, E. (2020): Internet of Things – the future of managing supply chain risks. In: Supply Chain Management: An International Journal, 25 (5), pp. 535–548.

Blei, D. M.; Ng, A. Y.; Jordan, M. I. (2003): Latent Dirichlet Allocation. In: Journal of Machine Learning Research, 3, pp. 993–1022.

Bower, J. L.; Christensen, C. (1995): Disruptive technologies: catching the wave. In: Harvard business review, 73 (1), pp. 43–53.

Chopra, S.; Sodhi, M. S. (2004): Managing Risk to Avoid Supply-chain Breakdown. In: MIT Sloan Management Review, 46 (1), pp. 53–62.

Chowdhury, M. M. H.; Quaddus, M. (2016): Supply chain readiness, response and recovery for resilience. In: Supply Chain Management: An International Journal, 21 (6), pp. 709–731.

Christensen, C. (1997): Patterns in the evolution of product competition. In: European Management Journal, 15 (2), pp. 117–127.

Christopher, M. (2016): Logistics & supply chain management. London: Financial Times/Pearson Education.

Christopher, M.; Lee, H. (2004): Mitigating supply chain risk through improved confidence. In: International Journal of Physical Distribution & Logistics Management, 34 (5), pp. 388–396.

Christopher, M.; Peck, H. (2004): Building the Resilient Supply Chain. In: The International Journal of Logistics Management, 15 (2), pp. 1–14.

Colicchia, C.; Strozzi, F. (2012): Supply chain risk management: a new methodology for a systematic literature review. In: Supply Chain Management: An International Journal, 17 (4), pp. 403–418.

Corbin, J. M.; Strauss, A. (1990): Grounded theory research: Procedures, canons, and evaluative criteria. In: Qualitative Sociology, 13 (1), pp. 3–21.

Craighead, C. W.; Blackhurst, J.; Rungtusanatham, M. J.; Handfield, R. B. (2007): The Severity of Supply Chain Disruptions: Design Characteristics and Mitigation Capabilities. In: Decision Sciences, 38 (1), pp. 131–156.

Dada, A.; Thiesse, F. (2008): Sensor Applications in the Supply Chain: The Example of Quality-Based Issuing of Perishables. In: Floerkemeier, C.; Langheinrich, M.; Fleisch, E.; Mattern, F.; Sarma, S. E. (Eds.): The Internet of things. First international conference, IOT 2008, Zurich, Switzerland, March 26-28, 2008; proceedings. Berlin: Springer, pp. 140–154.

Denyer, D.; Tranfield, D. (2009): Producing a systematic review. In: Buchanan D. A.; Bryman, A. (Eds.): The Sage handbook of organizational research methods. Thousand Oaks, CA: SAGE, pp. 671–689.

Dutton, W. H. (2014): Putting things to work: social and policy challenges for the Internet of things. In: info, 16 (3), pp. 1–21.

Ernst & Young (2020): Autokonzerne rutschen im zweiten Quartal tief in die roten Zahlen. Retrieved from www.ey.com/de_de/news/2020/09/ey-automotive-bilanzen-q2-2020 (accessed: 10 January 2021).

Fahimnia, B.; Sarkis, J.; Davarzani, H. (2015a): Green supply chain management: A review and bibliometric analysis. In: International Journal of Production Economics, 162, pp. 101–114.

Fahimnia, B.; Tang, C. S.; Davarzani, H.; Sarkis, J. (2015b): Quantitative models for managing supply chain risks: A review. In: European Journal of Operational Research, 247 (1), pp. 1–15.

Fan, H.; Cheng, T. C. E.; Li, G.; Lee, P. K. C. (2016): The Effectiveness of Supply Chain Risk Information Processing Capability: An Information Processing Perspective. In: IEEE Transactions on Engineering Management, 63 (4), pp. 414–425.

Fan, Y.; Stevenson, M. (2018): A review of supply chain risk management: Definition, theory, and research agenda. In: International Journal of Physical Distribution & Logistics Management, 48 (3), pp. 205–230.

Geng, Y.; Chen, W.; Liu, Z.; Chiu, A. S.; Han, W.; Liu, Z.; Zhong, S.; Qian, Y.; You, W.; Cui, X. (2017): A bibliometric review: Energy consumption and greenhouse gas emissions in the residential sector. In: Journal of Cleaner Production, 159, pp. 301–316.

Goh, M.; Lim, J. Y.; Meng, F. (2007): A stochastic model for risk management in global supply chain networks. In: European Journal of Operational Research, 182 (1), pp. 164–173.