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MANAGERIAL IMPACT FACTORS OF INNOVATION IN INTER-ORGANIZATIONAL SUPPLY CHAINS

Doctoral Thesis

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Contents

List of Abbreviation

Auto-ID	Automatic identification
EEX	European Energy Exchange
EDI	Electronic data interchange
Env	Environment / environmental characteristics
ERP	Enterprise resource planning (systems)
IT	Information technology
IoT	Internet of Things
kWh	Kilowatt hour
SC	Supply chain
SCM	Supply chain management
SCI	Supply chain integration
RFID	Radio Frequency Identification
ROI	Return on investment
Org	Organization / organizational characteristics
PLS	Partial least squares
Pro	Product / product context
Scr	Supply chain readiness
Scs	Supply chain effectiveness
Scy	Supply chain efficiency
Tec	Technology / technological fit

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Introduction

Actuality of topic

Today's supply chain management faces many challenges. Increasing market competition, new enabling technologies and changing market structures in the energy market including the ongoing energy transition create an immanent need for the new and innovations regarding supply chain management approaches in the power generation industry. The future competition might not only imply single companies. Networks of organizations, including suppliers and distributors, and therefore the total supply chain need to aspire innovation to gain competitive advantage.

The improvement of the company's overall performance including supply chain performance is of main interest of all business activities. Recent researches identify the need for a substantial advancement of process integration with external supply chain partners as one of ten mega-trends that will revolutionize supply chain activities. Numerous companies still perform a supply chain management with media discontinuity. The flow of information and financial assets is adjusted to certain automation. In contrast, the physical flow of material is still performed paper-based. A delivery note is attached to the material and transported by an in-house or by a third party logistic provider to the customer.

In contrast to the majority of actual business realities, researchers and economists discuss and promote concepts of future supply chain management. One main theory of future supply chain management is actually defined by the Internet of Things concept and terms like cyber-physical systems, 'Smart Factory' and the German research approach of 'Industrie 4.0', which is called 'Industrial Internet' approach in the United States of America. Enabling information technologies for supply chain innovation, such as RFID technology, are only implemented in selected intra-logistic applications or within closed supply networks like the automobile industry and its highly integrated strategic partners. However, it is uncertain whether a wide range of industries and its supply chain members can apply these trends and concepts into every day business operations. Further adoption of innovation as well as inter-organizational integration is needed within today's supply chain management.

The author's motivation to write this thesis is the ongoing research initiatives and industrial theories towards future supply chain management, such as Internet of Things, cyber-physical systems and the German economical concept of 'Industrie 4.0'. This thesis will add knowledge to research and practice regarding an increased supply chain performance by the adoption of innovation in inter-organizational supply chains.

Aim of the research

Author's aim of this research is the examination and evaluation of managerial impact factors of supply chain innovation in inter-organizational supply chains.

Tasks of the thesis

The main task of this thesis is the evaluation of the managerial impact factors for innovation in inter-organizational supply chains. In particular, the following tasks are addressed:

- To describe the needs of today's supply chain management for innovation for reaching the actual theories of virtual and real combined inter-organizational logistic processes.
- To analyse managerial impact factors for innovation and their casual relations in previous research.
- To develop a casual model of managerial impact factors for innovation in inter-organizational supply chains.
- To portray two relevant enabling technologies for supply chain innovation.
- To evolve a research design for testing the casual model, hypotheses and propositions in the German electricity generation industry and its suppliers.
- To analyse empirically gathered data of this research and state managerial impact factors for innovation in inter-organizational supply chains.
- To clarify the impact of the two relevant enabling technologies on supply chain innovation and performance.

The theses for defence

The theses for defence in the presented research address the following research question:

What are managerial impact factors for innovation in inter-organizational supply chains?

The main theses for defence in order to answer the research question are defined as:

- The adoption of innovation in inter-organizational supply chains increases the supply chain performance.
- Supply chain performance is constructed of supply chain effectiveness and supply chain efficiency.
- Enabling technologies for innovation, bar code and RFID technology, support supply chain performance in inter-organizational supply chains.

The research model, as stated in figure 3, consists of two latent variables: 'adoption of innovation in inter-organizational supply chain' and 'increase of supply chain performance'. The independent variable 'adoption of innovation in inter-organizational supply chains' is a constructed of four managerial impact factors: 'organizational characteristics', 'environmental characteristics', 'technological fit' and 'product context'. The variable 'supply chain readiness' is stated as an inductive factor of the four factors of innovation adoption.

The dependent variable ‘supply chain performance’ measures the impact of adoption of innovation on the supply chain performance. Supply chain performance is a construct of the two factors: ‘supply chain effectiveness’ and ‘supply chain efficiency’.

In this thesis, in the focus of today’s challenges of supply chain management and future concepts, the author arranges a novel construct of managerial impact factors for supply chain innovation, which influences the active management of processes, organizational structures as well as enabling technologies for actively manage the supply chain. Business managers need to be aware of theses impact factors and integrate these within their decision-making process regarding innovation projects.

The factor ‘organizational characteristics’ refers to internal resources that can be assigned to support an innovation. ‘Environmental characteristics’ focus on external influences such as economic condition, market competition and environmental uncertainty. The factor ‘technological fit’ evaluates the technological capacities regarding innovation at the administration level of the organization. ‘Product characteristics’ vary significantly and therefore might influence the innovation as well. ‘Supply chain readiness’ is identified as an intervening factor for inter-organizational supply chain innovation adoption and highlights the collaboration characteristics of the supply chain and its members.

This research model is applied in a comparative research design for three variations. Next to a general adoption of the research model, it is also adopted to two relevant enabling technologies for innovation in inter-organizational supply chains in order to accomplish concepts of future supply chain management.

The following propositions need to be addressed for testing of the hypotheses and the underlying research question:

- Proposition 1: The factors ‘organizational characteristics’, ‘environment characteristics’, ‘technological fit’ and ‘product context’ positively impact the supply chain effectiveness.
- Proposition 2: The factors ‘organizational characteristics’, ‘environment characteristics’, ‘technological fit’ and ‘product context’ positively impact the supply chain efficiency.
- Proposition 3: The factor ‘supply chain readiness’ supports the adoption of innovation in inter-organizational supply chains.
- Proposition 4: The increase of supply chain effectiveness by applying bar code technology as an enabling technology within supply chain innovation adoption is higher compared with RFID technology.
- Proposition 5: The increase of supply chain efficiency by applying RFID technology as an enabling technology within supply chain innovation adoption is higher compared with bar code technology.

The adoption of innovations in supply chain management and their further integration are essential for implementing the Internet of Things concept. The compared enabling technologies facilitate the identification of logistic items and the storage of static data. Bar code and RFID technology are the simplest form of Automatic Identification (Auto-ID) technology for achieving this identification compared to sensors networks. Based on today's practical and academic research, RFID technology offers an efficient option for achieving this goal due to the availability of automatically identification of logistic objects at a supply chain event. On the other side, RFID technology cannot be stated as an error free technology and therefore the globally proven bar code technology might be an initial and more effective approach towards the Internet of Things concept. In contrast to people and the Internet of People, logistic objects cannot register to the Internet of Things by themselves. The applied comparative research method aims to clarify differences of these two enabling technologies on supply chain innovation as well as supply chain performance and the Internet of Things concept. An increased supply chain performance of an Auto-ID technology in an inter-organizational supply chain states a possible application within the Internet of Things. If not, its actual potential for identification of logistic objects might not be sufficient for future's supply chain management concept.

Used methods

In this thesis, main research methodologies are sequential triangulation and the comparative research method.

The author of this thesis applies both, a qualitative and quantitative research method, in a sequential way. In the first stage of the data collection, qualitative research is used to identify the actual stage of research. In addition to a theoretical analysis of literature, semi-structured interviews with experts are carried out. Based on the results and findings of the first stage, data collection using the quantitative research method self-completion questionnaire survey is planed and executed. Hereby, the author uses comparative research method regarding the stated enabling technologies within supply chain innovation testing the stated hypotheses within the defined basic population in order to answer the research question.

The research results are stated according to the method of meaning condensation for the qualitative research part as well as applying multivariate statistics, such as structural equation modelling, Levene's and Mann–Whitney U test, for analysing the empirical data within the quantitative research part.

Approbation of the results of research

All research results have been provided to scientific research community for use and future research. The author has participated in eight national and international research conferences:

1. Paper “Error Reporting in Organizations” presented at the “International Conference for Business and Economics – Innovative Approaches of Management Research for Regional and Global Business Development“, University of Applied Science Kufstein, Austria, 3rd – 5th August 2012.
2. Paper “The Impact of Auto-ID Technology Adoption within inter-organizational Supply Chains” presented at the “International Scientific Conference - Interdisciplinary Scientific International Conference for PhD students and assistants - Quaere 2013“, Palacký University, Hradec Kralove, Czech Republic, 20th – 24th May 2013.
3. Paper “The Impact of Auto-ID Technology Adoption within Inter-organizational Supply Chains” presented at the “International Business and Economics Conference – Current Approaches of Modern Management and Strategy Research“, University of Applied Science Kufstein, Austria, 29th – 30th November 2013.
4. Paper “The Impact of Auto-ID Technology Adoption within inter-organizational Supply Chains” presented at the “Annual 72nd Conference of University of Latvia - Faculty of Economics and Management - Impact of globalization to national economies and business – 2014”, University of Latvia, Riga, Latvia, 5th February 2014.
5. Paper “Increasing intra-organizational supply chain performance by the vision of the Internet of Things” presented at the “International Scientific Conference - Conference of Informatics and Management Sciences - ICTIC 2014“, University of Zilina, Zilina, the Slovak Republic, 24th – 28th March 2014.
6. Paper “Managerial relevant impact factors on inter-organizational supply chain management” presented at the “International Scientific Conference – Virtual Multidisciplinary Conference - Quaesti 2014“, Palacký University, Olomouc, the Czech Republic, 15th – 20th May 2014.
7. Paper “Managerial Relevant Impact Factors on inter-organizational Supply Chain Management – Empirical Findings from Qualitative Research” presented at the “International Conference on Economics and Management of Business“, University of Zilina, Zilina, the Slovak Republic, 24th – 27th August 2015.
8. Paper “Managerial Relevant Impact Factors on inter-organizational Supply Chain Management - Empirical Findings from Quantitative Research” presented at the “2015 IIER 38th International Conference on Advances in Business Management and

Information Technology, Conference Proceedings“, International Institute of Engineers and Researchers (IIER), Zurich, Switzerland, 26th September 2015.

In addition, the author published at six international research conferences:

1. Willutzky, S., The Impact of Auto-ID Technology Adoption within inter-organizational Supply Chains, International Scientific Conference Quaere 2013 - Interdisciplinary Scientific International Conference for PhD students and assistants, Conference Proceedings, Vol. III, 2013, pp. 65-72, ISBN 978-80-905243-7-8.
2. Willutzky, S., Increasing intra-organizational supply chain performance by the vision of the Internet of Things, International Scientific Conference ICTIC 2014 - Conference of Informatics and Management Sciences, Conference Proceedings, ICTIC 2014, 2013, pp. 115-117, ISBN 978-80-554-0865-1.
3. Willutzky, S., Managerial relevant impact factors on inter-organizational supply chain management, International Scientific Conference Quaesti 2014 - Virtual Multidisciplinary Conference, Conference Proceedings, 2014, pp. 79-85, ISBN 978-80-554-0959-7.
4. Willutzky, S., Managerial Relevant Impact Factors on inter-organizational Supply Chain Management – Empirical Findings from Qualitative Research, The ICEMB 2015: International Conference on Economics and Management of Business, Proceedings of international conference on economics and management of business (ICEMB 2015), 2015, pp. 15-19, ISBN 978-80-554-1009-8.
5. Willutzky, S., Managerial Relevant Impact Factors on inter-organizational Supply Chain Management - Empirical Findings from Quantitative Research, 2015 IIER 38th International Conference on Advances in Business Management and Information Technology, Conference Proceedings, Volume III, 2015, pp. 11-16, ISBN 978-93-82702-07-8.
6. Willutzky, S., Managerial Relevant Impact Factors on inter-organizational Supply Chain Management - Empirical Findings from Quantitative Research, International Journal of Management and Applied Science, Volume 1, Issue 10, Nov. 2015, pp. 47-52, ISSN 2394-7926.

The author receives an award at the IIER 38h International Conference on Advances in Business Management and Information Technology, Zurich (Switzerland) in the category Best Presentation / Best Content for the paper “Managerial Relevant Impact Factors on inter-organizational Supply Chain Management - Empirical Findings from Quantitative Research”.

Structure of dissertation

This thesis is structured in three main parts as shown in appendix 2 and framed by this introduction part as well as by the part conclusions and suggestions. An overview of the research process performed by the author in this thesis is illustrated in figure 12.

The first part covers the role and actual relevance of supply chain management in today's business organizations. After stating relevant definitions regarding logistics, supply chain management and their integration, the author refers to the state of the art theory of future supply chain management, the concept of Internet of Things. Systems theory and utility theory, as one part of decision-making theory, are introduced as a basis for managerial impact factors of innovation for reaching future supply chain integration and underlying increase of supply chain performance. Based on literature review, the theoretical framework of managerial impact factors for inter-organizational supply chain innovation is deducted.

In the second part and linked to the comparative research method, the state of the art of two enabling technologies in supply chain innovation, RFID and two-dimensional bar code technology, within the concept of the Internet of Things is presented. In the following, the approach taken for this study regarding the German business sector electricity power generation without transmission including its ongoing market changes and necessity for supply chain innovation is explained. Concluding this chapter, the research methodology and the research design, including relevant aspects regarding expert-interviews and self-completion questionnaires are presented.

The third part states the research results for each qualitative and quantitative research method and a reflection and interpretation of thesis' overall research results.

The final part 'Conclusions and Suggestions' states the conclusions regarding the main thesis for defence as well as the deduced propositions. The suggestions regarding the proposed novel construct of managerial impact factors for innovation in inter-organizational supply chains are stated addressing both managerial and theoretical implications.

Limitations

Limitations of this research, which can be followed by future researchers, are related to the basic population, the selected managerial impact factors and limiting legal aspects within the execution of the qualitative research method.

- The basic population is limited to the German electricity generation industry and its suppliers. Future researchers are asked to apply the research approach to further settings, covering further industries as well as national and international economical settings.

- Next to the stated and researched managerial impact factors for innovation in inter-organizational supply chains, the author states additional potential impact factors future researchers are encouraged to research.
- The inductive latent variable ‘supply chain readiness’ is correlated in this research to the adoption of supply chain innovation in inter-organizational supply chains. Future research might also address ‘supply chain readiness’ as an exogenous latent variable hypothesising a directly positive effect on supply chain performance.
- Due to given legal restrictions of the German cartel law, the author is limited within the qualitative research method and the selection of experts for the semi-structured interviews in the electricity generation industry. Even though this limitation is compensated by an adapted selection of experts, future research from outside the industrial sector might address this issue.

Overall, the author is aware of the limitations of both research methods and its combination within the triangulation research approach. With the intent to minimize the stated limitations, quality criteria for this research are defined and followed.

Main results

This thesis improves the in-depths knowledge of relevant managerial impact factors for an innovation in inter-organizational supply chains by addressing the stated research question.

The author can state the following conclusion regarding the stated main theses for defence as one main result of the research process.

- The adoption of innovation in inter-organizational supply chains increases the supply chain performance. -> partly substantiated
- Supply chain performance is constructed of supply chain effectiveness and supply chain efficiency. -> substantiated
- Enabling technologies for innovation, bar code and RFID technology, support supply chain performance in inter-organizational supply chains. -> rejected

The following propositions have been addressed for examining the hypotheses and the underlying research question.

The author partly substantiates proposition 1 and 2, substantiates proposition 3, and rejects proposition 4 and 5 based on the results of the empirical data analyses in this research.

The stated recent researches, supported by the thesis’ research results, identify the need for a substantial innovation of process integration with external supply chain partners in order for reaching today’s theories of future supply chain management.

The author of this thesis identifies supply chain innovation as necessary for meeting the stated predatory market competition in the German electricity power generation industry in which currently most supply chain transactions are performed with media discontinuity.
The author provides a valid and reliable scale of measurement in form of an interview guide and questionnaire for the novel construct of managerial impact factors for innovation and their impact on supply chain performance covering effectiveness and efficiency within inter-organizational supply chains.
Business organizations are requested to apply the derived construct of antecedents of supply chain innovation in inter-organizational supply chains within their decision-making process. Business organizations are requested in particular to consider the factors ‘product context’ and ‘technological fit’ for increasing effectiveness within the adoption of innovation in inter-organizational supply chains. For increasing inter-organizational supply chain efficiency, business organizations need to take into account the determinant ‘product context’ in the decision-making process for adopting and implementing supply chain innovation.
Business organizations might focus on the readiness of the underlying supply chain and its supply chain partners within the decision-making process, in particular on the indicators ‘bargaining power’ and the presence of existing ‘inter-organizational dependencies’.
Supply chain managers need to critical assess the adoption of the two enabling technologies for innovation in the underlying inter-organizational supply chain. In accordance with the homoscedasticity of the population variances for the two groups ‘bar code’ and ‘RFID’, a reliable and valid difference of the two enabling technologies cannot be stated.
The bar code technology, in particular the two-dimensional and QR code - meets the requirements of industrial future concepts. Bar code as well as RFID technology will be part of these concepts. Interviewees stated the limitations of bar codes within the ‘Industrie 4.0’ concept, which ultimately contains smart supply chain objects with the capacity to ‘think’.

Novelty

This thesis has to been seen in combination to other studies of the research problem. By using triangulation for researching a single phenomenon, the personal biases of investigators - including the author of this thesis - should be avoided and the deficiencies of a single-investigator, single-theory or single method study should be overcome promoting greater confidence in the observed findings. The novelty of this research can be stated as following:

1. Managerial impact factors for innovation are combined in an approach for inter-organizational supply chain management.

2. Supply chain readiness is stated as an inductive latent variable on adoption of innovation. Supply chain readiness supports innovation in inter-organizational supply chains resulting in an increase of supply chain performance.
3. Two enabling technologies for innovations in integrated supply chain management, bar code and RFID technology, are combined in a comparative research design.
4. Supply chain innovation is researched within inter-organizational supply chains, in contrast to most previous studies that mainly research changes within a single organization or closed supply chain management networks.
5. The author designs a new measurement scale of managerial impact factors for innovation and their influence on supply performance, including supply chain effectiveness and efficiency, based on actual state of the art of research literature.
6. The author states empirical findings, highly relevant also for practical implementers, on managerial impact factors of innovation for the supply chain in the German electricity generation industry.

Used sources

The author identifies the research model construct and researched managerial impact factors for supply chain innovation from a literature review covering relevant studies published to date in main international business management and supply chain/logistic journals.

International scientific journal articles in relevant databases as well as books and additional articles such as reports, newspaper articles and working papers were reviewed and evaluated. The following topics are researched in detail: supply chain management, supply chain integration, innovation, RFID and bar code technology.

Main contributors (leading authors) are:

- Managerial impact factors for supply chain innovation: Christina Quetti, G. Premkumar She-I Chang, Everett M. Rogers, Kirk A. Patterson, Suhaiza Zailani, Aditya Sharma, and Ada Scuploa.
- Innovation and innovation processes: Louis G. Tornatzky, Mitchell Fleischer, and Everett M. Rogers.
- Supply chain management and its future concepts: John T. Mentzer, Daniel J. Flint, Dag Näslund, Dieter Uckelmann, Manfred Broy, and Lisa Becher.
- Relevant enabling technologies in supply chain management: Pamela J. Zelbst, Kenneth W. Green, Aysegul Sarac, and Chia-Chen Chao.
- Research methodology and research design: Brace (2013), Fink (2013), and Kvale and Brinkmann (2013).
- Statistical analysing procedures: Urbach and Ahlemann (2010) and Nitzel (2010).

Additional literature regarding further scientific theories and fields of research has been reviewed and applied by the author.

The thesis' supervisor, members of the doctoral program as well as the internal reviewers from the Faculty of Economics and Management at the University of Latvia guided the author in the process of research within this thesis. Advice is given regarding e.g. formulation and statement of theses for defence, defining the research design for the both qualitative and quantitative research methodology, analysing the empirically gathered data, and statement of conclusions and suggestions. The consultations took place in personal meetings with the supervisor and members of the doctoral program as well as in department meetings next to regular email communication.

Words of gratitude

At this stage, special thanks shall be expressed to all managers who have been available for expert interviews and to those industry professionals who have taken time to complete the survey.

Furthermore, gratitude is extended towards the University of Latvia, Faculty of Economics and Management, in particular to Dr. math., professor Māra Gulbe for her continued support and dissertation supervision as well as the internal reviewers for assisting in thesis' finalisation. The author extends his sincere thanks to Prof. Dr. Josef Neuert and Manuel Woschank for their support in the statistical analysis of the empirical research data.

1. Impact of Innovation on Supply Chain Integration for Meeting Future Concepts

The role and actual relevance of supply chain management (SCM) and its integration in today's business organizations is presented in the following. It will be referred to the state of the art theories of future supply chain management, the concept of Internet of Things.
The definitions of key terms such as supply chain (SC) and its management need to be clarified before approaching to the literature review and the state of the art concepts.
In the following, the Internet of Things concept will be discussed as a future scenario, requesting further for supply chain innovation and integration. The Internet develops from an Internet of Texts to an Internet of People using Social Media. Today's concept describes an Internet of Things including 'smart objects', which has a major impact to future supply chain management.
Systems theory and utility theory, as a part of decision-making theory, are introduced as a basement for managerial impact factors for innovation for reaching future supply chain integration and underlying increase of supply chain performance.
Based on literature and actual research, five managerial factors for innovation in inter-organizational supply chain management are derived and presented in a newly combined way: 'organizational characteristics', 'environmental characteristics', 'technological fit', 'product context' and 'supply chain readiness' as an initiator. At the end of the chapter, the research model is stated as the bases for the empirical research including sequential triangulation combined with comparative research.

1.1. Supply chain management requirements for further integration and innovation

The management of the supply chain has become an integrated and essential part of business and management. In the following, relevant terms according the supply chain, its management and integration are defined.

1.1.1. Role of logistics and supply chains in business organizations

The idea of a coordinated logistic management can be traced back to at least 1884 and the writings of Jules Dupuit, a French engineer, in which he finds evidence for the selection between road and water transport in trading one cost for another (transportation cost for inventory cost). In mid of the 20th century and especially during World War II, the term logistic is mainly associated with military but gradually spread to cover business activities. Logistics, in military science, includes all the activities of armed-force units in roles supporting combat units, including transport, supply, signal communication, medical aid, and the like."[1]

In 1961, the first textbook by Smykay et al. appears suggesting the benefits of coordinated logistics management and explaining why a generally accepted definition of business logistic is still emerging.[2] In 1962, the Council of Supply Chain Management Professionals, a professional organization of logistic managers, educators and practitioners is formed for the purpose of continuing education and fostering the interchange of ideas relating business logistic.[3] The actual and widely accepted definition of the term 'logistic' according to the Supply Chain Management Professionals (2010):

"Logistics management is that part of supply chain management that plans, implements, and controls the efficient, effective forward and reverse flow and storage of goods, services, and related information between the point of origin and the point of consumption in order to meet customers' requirements."[4]

This definition is based on the idea of managing product flows from the point where they exist as raw materials to the point where they are finally discarded. In addition, the flow of services as well as products is covered by a logistic process, which includes all the activities that have an impact on making products and services available to the customer's point of requirement. However, the stated definition by the Supply Chain Management Professionals reflects only a part of the supply chain and its management.[5]

Today the term 'supply chain' seems to be commonly defined across authors. Mentzer et al. (2001) defines supply chain as following:

"A supply chain is defined as a set of three or more companies directly linked by one or more of the upstream and downstream flows of products, services, finance, and information form a source to a customer."[6]

The supply chain can be distinguished between four types - the basic supply chain, an extended supply chain, an ultimate supply chain and a partnership.

A basic or direct supply chain consists of a company, an immediate supplier and immediate customer, which are directly linked by one or more of the upstream and downstream flows of products, services, finances and information.

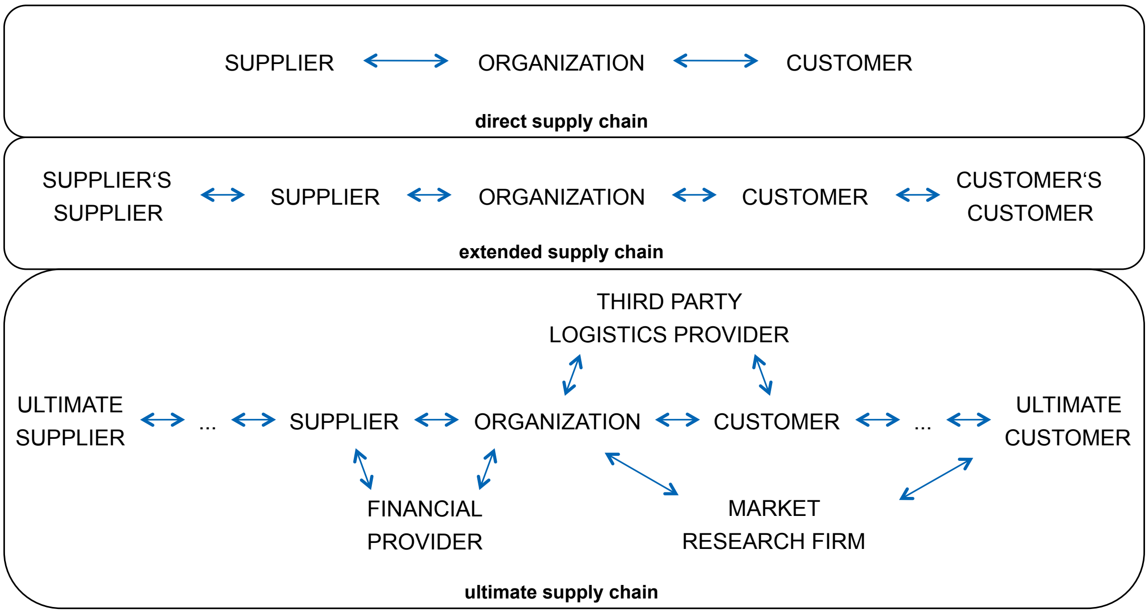
[1] cf. Ballou (2004), p. 3-4
[2] cf. Smykay et al. (1961), pp. 4
[3] cf. Ballou (2004), p. 4. The organization is formerly known as the Council of Logistics Management.
[4] Council of Supply Chain Management Professionals (2010), p. 114
[5] cf. Lambert and Pohlen (2006), p. 201 and Ballou (2004), p. 5
[6] Mentzer et al. (2001), p. 5

An extended supply chain includes suppliers of the immediate supplier and customers of the immediate customer. All parties are linked by one by one or more of the upstream and downstream flows of products, services, finances and information.

An ultimate supply chain includes all companies involved in all the upstream and downstream flows of products, services, finances and information from the initial supplier to the ultimate customer.

A partnership or an alliance constitutes the cooperative relationship between two companies in distinction from the supply chain. This type of relationship does not involve any one company in simultaneous upstream and downstream relationships.[7]

The author presents these types of channel relationships among the supply chain in figure 1. The two-way arrows indicate that more than just products flow through supply chains and partnerships. In addition to services and finances, information regarding a product and its flow covered by Auto-ID technology might be included.



Source: derived by author from Mentzer et al. (2001), p. 7

Figure 1. **Types of supply chain relationships**

As phenomena of business, the direct, extended and ultimate supply chain as presented in figure 1 exists in business life without actively implemented by one of the involved. The supply chain is reduced to a collection of functional activities, which is repeated many times throughout the channel. Many other researchers and authors in literature use this fact as the demarcation between supply chains as phenomena that exist in business and an actively management of these supply chains.[8]

[7] cf. Mentzer et al. (2001), p. 6-7

[8] cf. Ballou (2004), p. 7 and Mentzer et al. (2001), p. 6-7

The stated theories of logistics, supply chains and its management continuously request new and innovative for implementing the management of ultimate supply chains in the businesses world – also stated in today's concept of the Internet of Things and 'Industrie 4.0', which will be presented in chapter 1.2.

1.1.2. Evolution from management to integration of supply chains

The idea of coordinative integration around the supply chain is not new.[9] Since the 1990s, the term 'supply chain management' has risen to prominence. According to Ross (1998), the SCM has become such a hot topic, that it is difficult not to pick up a publication relating to manufacturing, distribution, marketing, customer management, or transportation without covered SCM or SCM-related aspects.[10] Reasons for the rising popularity of the SCM concept are manifold such as:[11]

- Globalization is intensifying due to increasingly global sourcing corporations. Companies are forced to manage a globalized supply chain in regard to find an effective way to coordinate the flow of materials into and out of the company.
- Competition is increasing between companies and distribution channels on the basis of time and quality. Customers demand products consistently delivered faster, exactly on time and with zero-defect which requires a closer coordination with suppliers and distributors.
- Uncertainty of marketplaces due to rapidly changing technologies and economic conditions are a further result of an increased global performance-based competition.

Most SCM definitions relate to the integration of functional supply chain activities. Several benefits are clearly stated in literature. However and in contrast to the definition of the supply chain, there is no widely accepted definition on of supply chain management or even related topics as supply chain integration or supply chain collaboration.[12] Some common aspects are presented at this point, a closer examination and in relation to Auto-ID technology is carried out in the following chapter.

Reviewing literature, the stated SCM definitions mostly contain multiple firms, multiple business activities and the coordination of those activities across functions and across firms in the supply chain.

[9] cf. Prahalad and Hamel (1994), p. 10
[10] cf. Ross (1998), p. 1. Cooper et al. (1997), p. 1 is dating the appearance to the mid-1980.
[11] cf. Hahn-Woernle (2010), p. 12, Näslund and Hulthen (2012), p. 482, and Mentzer et al. (2001), p. 3-4
[12] cf. Näslund and Hulthen (2012), p. 482 and Mentzer et al. (2001), pp. 11

Lambert and Pohlen (2006) highlight in their definition of ‘supply chain management the cross-functional integration within the firm and across the network of firms that comprise the supply chain.[13]

The Council of Supply Chain Management Professionals developed the following definition of supply chain management:

"Supply Chain Management encompasses the planning and management of all activities involved in sourcing and procurement, conversion, demand creation and fulfilment, and all Logistics Management activities. Thus, it also includes coordination and collaboration with channel partners, which can be suppliers, intermediaries, third-party service providers and customers. In essence[,] Supply Chain Management integrates supply and demand management within and across companies."[14]

Mentzer et al. (2001) proposes a broad and rather general definition of supply chain management:

"Supply chain management is defined as the systemic, strategic coordination of the traditional business functions within a particular company and across businesses within the supply chain, for the purposes of improving the long term performance of the individual companies and the supply chain as a whole."[15]

In reference to literature, the purpose of active management of the supply chain is adding value for the customers. Michael E. Porter (1985) is referring to the term ‘logistic’. However, he identifies the inbound and outbound logistics as a primary activity involved in competing in any industry with the overall goal to achieve a competitive advantage. Mentzer et al. (2001) names as a consequence of the management of the supply chain the lowering of cost, an improved customer value and satisfaction and therefore a completive advantage. For Copper et al. (1997), the key for adding value for customers is the integration of business processes from the end-user to the original suppliers that provide products, services and information.[16]

In theory, the definition of the term ‘supply chain integration’ on top of the term ‘supply chain’ and ‘supply chain management’ turns out to be even more difficult. Due to the confusing terminology, such as the lack of a clear definition and understanding of the notion of SCM, the lack of empirical evidence of integration of supply chains beyond the dyadic level, and the lack of understanding regarding the implementation of integration prevents the

[13] cf. Lambert and Pohlen (2006), p. 201

[14] Developed by the Council of Supply Chain Management Professionals - formerly Council of Logistic Management (2003), cited in Gibson et al. (2005), p. 22

[15] Mentzer et al. (2001), p. 22

[16] cf. Porter (1985), p. 39-40, Mentzer et al. (2001), p. 15, and Cooper et al. (1997), p. 2

development of normative definitions to literature and practitioners of why, how, when and what to integrate.[17]

A broader definition of supply chain integration focuses on the extent to which supply chain members work cooperatively together to achieve mutually acceptable outcomes.[18]

Flynn et al. (2010) define supply chain integration (SCI) as the degree to which a manufacturer strategically collaborates with their supply chain partners and collaboratively manages intra- and inter-organizational processes. The goal is to achieve effective and efficient flows of products and services, information, money and decisions, next to provide maximum value to the customer at low cost and high speed.[19]

Froehlich and Westbrook (2001) extended the discussion by simultaneously examining the upstream and downstream integration.[20]

Näslund and Hulthen (2012) are also referring to the collaboration or coordination of the management efforts. In addition, it is highlighted that the management has to be focused to key suppliers and key customers.

"Supply chain management integration is the coordination and management of the upstream and downstream product, service, financial and information flows of the core business processes between a focal company and its key supplier (and potentially the supplier's key suppliers) and its key customer (and potentially the customer's key customers)".[21]

For this research, the author enhances the terms 'logistic' and 'supply chain management' to a network approach in which the flow of items is analysed and the underlying work-sharing activities are modelled as networks of supply chain members.

The stated challenges for modern supply chain management and its further integration request innovation from all members of supply chain – especially to reach the concept of future supply chain management: the Internet of Things.

1.2. Concept of Internet of Things and its effect on supply chain integration

An efficient and effective management of supply chains requires detailed and real-time information about the products and their actual location.

The importance of the information technology in an integrated supply chain management environment has risen in the 1980s. Prior to this time, a significant portion of the information flow between functional areas within an organization, and in an integrated supply chain with

[17] cf. Näslund and Hulthen (2012), p. 482-483
[18] cf. O'Leary-Kelly and Flores (2002), p. 226
[19] cf. Flynn et al. (2010), p. 59
[20] cf. Frohlich and Westbrook (2001), p. 195 and Kannan and Tan (2010), p. 207
[21] Näslund and Hulthen (2012), p. 496

its different supply chain organizations, is paper-based. These paper-based transactions and communications are slow, unreliable and error proven and therefore decreasing the company's efficiency in being able to design, develop, procure, manufacture and distribute its products. On theses grounds, the paper tagging systems begin of being replaced by a broad class of innovative enabling technologies called Automatic Identification and Data Capture, ADIC. The procedure of automatic data capture in logistics covers the identification of items, the automatic capture of relevant data and the communication with a database.

In reference to economical and political aspects, several research initiatives have been recently released. The Federal Government of Germany adopted an action plan for high technology research and innovation projects in Germany. One of the ten projects is named 'Industrie 4.0' which also can be referred as the fourth industrial revolution. Driven from technological innovations of combining real and virtual items in the so-called Internet of Things, 'Industrie 4.0' should embrace process innovations for the energy, transport and industry sector.[22] This development process has already started and will impact the competitive position of the German economy in ten or fifteen years.[23] The identification of items in the Internet of Things and cyber-physical systems in a tag-sensor combination will form the future 'Smart Factory' including 'Smart Logistics'.[24]

Emanating from the goals of the Internet of Things and 'Industrie 4.0', virtualization and collaboration among supply chain members are main challenges for creating these prospective smart logistic processes. Objects of the real world have to be virtualized to create a so-called physical awareness within the Internet of Things.[25] The evolutional process is schematized in appendix 1. Actual enabling technologies in supply chain innovation, such as RFID technology, will be a key technology in this development.

The Internet of Things (IoT) is an integrated part of the Future Internet including existing and evolving Internet network developments. It represents the role of future supply chain management including smart objects, which are automatically virtualized.

Vermesan and Friess (2011) state the following definition:

"The Internet of Things is formed by the networked interconnection of everyday objects and is involving self configuring wireless networks of sensors that create a world where

[22] cf. Federal Government of Germany - Federal Ministry of Education and Research (2012), pp. 6 and Gillhuber (2012), pp. 138

[23] cf. Coalition agreement for 18th legislative period of the Federal Republic of Germany of CDU, CSU, SPD, 2013, p. 19 and Broy (2013), p. 23-24

[24] cf. Broy (2010), pp. 21 and Cain and Lee (2008), p. 61

[25] cf. Acatech (2012), p. 24 and Geisberger and Broy (2012), p. 129

everything in it sends information to other objects and to people. In this world, everything is tagged and communicating provides information and knowledge."[26]

The Internet of Things European Research Cluster defines the Internet of Things as one element of the Future Internet and expects up to 16 billion connected devices by the year 2020. Other elements are for example the Internet of Energy including smart grid. The basis element within the Internet of Things is the ideal conception of a smart object and its different types such as activity-aware object, policy-aware object and process-aware object.[27]

As illustrated in appendix 5, the development of the Future Internet of Things and People can be considered as a phased approach. Today's existing Intranet of Things, for example in-house RFID installations, and Extranet of Things need to be extended open-loop RFID applications supported Internet architectures.

Today's Extranet of Things can be described by a limited number of preferred partners use electronic data interchange communication standard (EDI).[28]

Five levels of technical capabilities can be stated as relevant for implementing the Internet of Things and underlying cyber-physical systems such as autonomous control:

Level 1 represents the simplest form of RFID or any other Auto-ID technology to identify logistic items and store static data, which does not change over the product life cycle.

Level 2 uses enhanced Auto-ID technology to store dynamic data, such as time, location and sensor-based captured data like temperature or humidity.

Level 3 includes intelligent logistic objects processing data in order to create new, pre-processes data and solve tasks.

Level 4 cover logistic objects, given the capacity to exchange data in order to interact.

Level 5 is the final step to autonomous logistics and intelligent information based material handling. In flexible material handling systems, dynamic data is exchanged between product components and assembly robots.[29]

Numerous researchers formulate critique of the Internet of Things concept. Van Kranenburg (2008) examines impact of ambient technology and the all-seeing network of RFID on the wider society.[30] Main critique related to the Internet of Things focuses on privacy and security.

[26] cf. Vermesan and Friess (2011), p. 1
[27] cf. Pflaum and Hupp (2007), p. 108-109, Vermesan et al. (2011), p. 13, and Hersent et al. (2012), pp. 271
[28] cf. Uckelmann et al. (2011), pp. 2
[29] cf. Uckelmann et al. (2010), p. 170-171 and Scholz-Reiter et al. (2008), p. 185
[30] cf. Kranenburg (2008), p. 18-19

Botero and Chaouchi (2010) state, that "RFID technology is one of the leading enabling technologies in building the Internet of Things, since inanimate objects in daily life will join this network via this technology"[31].

The future of data appears even bigger - a challenge for most companies for generating business value from the Internet of Things. Even technological standards like the EPCglobal architecture are only a first step towards an increased supply chain visibility.

The author identifies the Internet of Things as a relevant theory of future supply chain management - without a solid business case and seems uncertain with today's technology.[32] Both facts are requiring innovation for reaching theories of future supply chain management.

In the following chapter, systems theory and utility theory, as a part of decision-making theory, are introduced as a basement for five managerial impact factors for innovation for reaching future supply chain integration and underlying increase of supply chain performance.

1.3. Systems theory and utility theory as foundation of supply chain integration

Both systems theory, including the resource-based view, and utility theory are relevant for decision-making processes and measuring the impact of the implementation of an innovations in supply chain integration.

1.3.1. Systems theory highlights the complexity in innovative change

Systems theory is developed after 1940 on the basis of suggestions by different fields of science, such as biology, physiology and information theory and cybernetics. Particularly, the idea of defining information as a selection among possibilities turns out to be a generalization transcending heterogeneous system. The term ‘systems theory’ originates to the work of Bertalanffy who realized the need for developing universal principles applying to systems in general. Today, two main variants forms of systems theory exist: a general systems theory in fields of biology, chemistry, physics and mathematic and a paradigm of sociological theorizing and research lined to the writing of Parsons and Luhmann. Defee et al. (2010) rank systems theory - next to competitive and microeconomic theory – as most frequently applied theory in logistic research.[33]

Systems theory was first applied to organization and management by Johnson et al. (1963). According to Johnson et al. (1963), business managers have to bring all individual, often

[31] Botero and Chaouchi (2010), p. 129

[32] cf. Pflaum and Hupp (2007), p. 107, Bucherer and Uckelmann (2011), pp. 265, Uckelmann and Scholz-Reiter (2011a), p. 78, and Uckelmann et al. (2011), p. 3-4

[33] cf. Defee et al. (2010), pp. 411, Parsons (1977), p.145, Bertalanffy (1968), p. 32, and Stichweh (2011), pp. 2579. Defee et al. (2010) perform a content analysis of 683 research articles in logistic and supply chain management research during the period 2004-2009.

diverse, functions of a business to an integrated and organized system to achieve a common organizational goal. Systems theory predicts that changes or actions taken in one subsystem impact the other subsystems as well as the whole system.[34] Luhmann (2013) states the term 'systems theory' according to the approach of researching a system and the effect of changing variables from different interdisciplinary perspectives.[35]

Stichweh (2011), a scholar of German sociologist and prominent thinker in sociological systems theory Niklas Luhmann, defines systems theory as following:

"Systems theory is a science which has the comparative study of systems as its object. There are different types of systems: organisms (animals, humans and particularly cognitive mechanisms in organisms), machines (particularly computers), physicochemical systems, psychic systems and social systems."[36]

Systems theory is applied as the basic theory in this thesis. Zelbst et al. (2012) apply systems theory to supply management by stating that supply chain management is a creation a finely turned collection of subsystems, which share information - and sometimes resources - in order to achieve common goals. Subsystems within supply chain management can be defined as supply chain members.[37] Overall, innovation in supply chain management is needed to optimize these subsystems – processes, organizational structures and enabling technologies. In particular, Auto-ID technology is one enabling technology to identify objects and facilitate the supply chain members to share information in order to increase supply chain performance.

Systems theory explains in the general view on (sub-) systems and their particular kind, the nature of their component elements and the relation or 'forces' between them. Systems theory differentiates between the elements of suprasystem and subsystem. A suprasystem is the entity that is composed of a number of component systems organized in interacting relationships in order to serve their embedding suprasystem. A subsystems is one component of a suprasystem made up of two or more interacting and interdependent components and interact in order to attain their own purpose(s) and the purpose(s) of the system in which they are embedded.[38]

One of Bertalanff's systems inquiry domains is technology, such as Auto-ID technology within supply chain management. As defined before and in reference to Mentzer et al. (2001), a direct supply chain and even an extended supply chain can be identified as a subsystem within the ultimate supply chain representing the suprasystem. The utilization of Auto-ID technology might assist in the integration of the subsystems into a suprasystem.

[34] cf. Johnson et al. (1963), p. 52 and Zelbst et al. (2012), p. 331
[35] cf. Luhmann (1995), pp. 20
[36] Stichweh (2011), p. 2579
[37] cf. Zelbst et al. (2012), p. 331
[38] cf. Bertalanffy (1968), p. 32 and Luhmann (1995), p. 21

The systems theory and the resource-based view theory both evaluate whether the firm's strategy, such as a further integration of the supply chain, creates value. The resource-based view concentrates on the firm's resources that add value and can be managed. This view proposes, that the competitive advantage derives from the information and other resources of the firm. In contrast, Porter's competitive forces framework focuses on economic and technical characteristics of the firm's industry as source of competitive advantage.[39]

Due to the limited perspective and ignoring external industry factors of the resource-based view, the measurement of supply performance in this thesis is based on the approach of systems theory. Supply chain management can be seen as the creation of a finely tuned collection of internal and external subsystems (supply chain members) that share information and sometimes resources in order to achieve common goals.[40] Dyer and Singh (1998) call this a "relational view" of inter-organizational completive advantage considering a dyadic/network unit of analysis in contrast to the resource-based view of individual firms.[41]

In this thesis and next to systems theory, utility theory is applied regarding the decision making process within supply chain innovation in inter-organizational supply chains.

1.3.2. Utility theory indicates the need for innovation

Within supply chain integration, utility theory can be applied to describe the process of decision making under risk, such as the implementing of an innovation in a (inter- and intra-organizational) supply chain.

(Classical) Decision theory can be stated as a mathematical theory concerned with choices. The expected utility theory is a normative model of rational choice. It is widely applied as a descriptive model of economic behaviour and game theory. Utility represents the - cardinal or ordinal scaled - preference over some set of goods and services. Utility is combined as a weighting factor with the probability or expected value of an outcome to make a choice, e.g. the decision maker's preference over some set of goods and services. Daniel Bernoulli states the idea of maximization of expected utility first explicitly in 1738.[42]

Classical economists and decision theorists call this "wantability". The expected utility represents and measures the satisfaction/happiness/utility from a good or a service. For example, how much the good or service will satisfy the human wants and will provide utility.[43]

[39] cf. Barney (1991), p. 105-106, Porter (1985), p. 5, Pearlson and Saunders (2009), p. 62, and Grant et al. (2010), p. 5
[40] cf. Priem and Bulter (2001), p. 31-32 and Zelbst et al. (2012), p. 331
[41] cf. Dyer and Singh (1998), p. 676 and Chen and Paulraj (2004), p. 121
[42] cf. Bertalanffy (1968), p. 22, and Gilboa (2009), p. 78
[43] cf. Kahneman (2012), p. 377

Within decision-making process for choices under uncertainty, the utility function computes expected utility rather than expected financial value. The utility function is usually applied as an indifference curve for two or more sets of good or services. Utility theory is a useful way of looking at consumer behaviour to assume that they maximizing utility. Business managers who have to make choices might also apply the principles of utility theory to a presented business decision, such as a decision of implementing an innovative technology in a supply chain between organizations, measured by benefits and costs. If the marginal utility for the decision makers remains positive, the implementation of an innovative technology will be realized. For example, Angeles (2007) proposes the expected utility theory as one explanation of utilization of RFID technology in supply chain management to promote or increase efficiency and therefore the performance of a supply chain.[44]

One limitation of the utility theory is the question weather decision-making processes can be stated as rational or irrational. Behavioural economist developed an alternative model for decision making under risk, called prospect theory. Behavioural economists, such as Daniel Kahnemann, use "wantability" for the term 'decisions utility' that also refers to hedonic or experienced utility.[45]

The expected utility theory, as well as systems theory, remains the basis of analysing choices among risky projects with (possibly multidimensional) outcomes.

The implementation of innovation, such as a supporting or even enabling technology, within the supply chain can lead to attaining and sustaining a competitive advantage. Porter (1985) introduces the concept of the value chain, which disaggregates an organization into strategically relevant activities – in conformity with systems theory and the stated supra- and subsystems. A single firm's value chain is embedded in a lager system of activities and part of an overall value system. Therefore, the firm's supply chain performance according to the value stream approach is influenced by the long-term success of the extended or even ultimate supply chain as stated before by Mentzer. This overall value system - the suprasystem within systems theory - includes the interactions between a group of supply chain partners, such as external suppliers, customers and the departments involved in the primary and secondary activities within the organization.[46]

Bowersox et al. (2000) identify the need for a substantial advancement of process integration with external supply chain partners as one of the ten mega-trends that will revolutionize the supply chain logistics.[47]

[44] cf. Angeles (2007), p. 465 and Fishburn (1970), pp. 103
[45] cf. Kahnemann and Tversky (1979), p. 263, Kahnemann (2012), pp. 377, and Shiller (2005), pp. 31
[46] cf. Porter (1985), p. 33-34, Basu (2011), p. 16, and Weber and Kantamneni (2002), p. 312
[47] cf. Bowersox et al. (2000), p. 9

Further supply chain integration and collaboration between supply chain members is not only a technical issue. Moreover, it is also a social and organizational one as well as a matter of trust. Kosanke (2005) points out, that during the engineering and realization of supply chain collaborations all these aspects have to be dealt with equally. Meanwhile, there is a significant difference between these aspects regarding understanding the problem and the potential of the solution. Technology behaviour is mainly predictable and its issues are usually understandable and appear solvable. In contrast, human behaviour is more likely non-deterministic and requires different methods in solving these so-called soft issues.[48]

Therefore, supply chain partners clearly have to state the goals, requirements and responsibilities of each supply chain member at the beginning of an engineering and implementation of an innovation. Trust and an open communication by sharing knowledge at all management levels across organizational boundaries might be vital to turn the project into a successful one.

The author concludes that within decision making, especially within decision-making processes for choices under uncertainty, certain impact factors might be of particular importance. The author derives in chapter 1.4. managerial impact factors of innovation in supply chain integration according to actual research. At the end of chapter one, the author states the research model based on the need for future supply chain integration.

1.4. Managerial impact factors of innovation in supply chain integration

The author presents in chapter 1.4.1. at first an overview of the state of the art regarding managerial impact factors for supply chain innovation and secondly the relevant managerial impact factors for innovation in inter-organizational supply chains researched in this thesis. The sub-chapters 1.4.2. to 1.4.7. derive the factors/indicators of the research model in more detail. Finally, sub-chapter 1.4.8. presents the research model of this thesis.

1.4.1. State of the art regarding managerial impact factors for supply chain innovation

The successful implementation of innovation is a key aspect in further supply chain integration and collaboration Supply chain collaboration, as one form of nowadays also called collaborative networks among trading partners, has become a source of competitive advantage. Technological innovation, in particular information and communication technology, provides the basis to enable the collaboration partners to improve the flow of information, goods and finance resulting in increased shareholder value and overall supply chain performance.

[48] cf. Kosanke (2005), pp. 6

Numerous studies describe single advantages of a technology or they frame the complexity of the decision and adoption process in an inter-organizational context. In this study, the main factors driving innovation in inter-organizational supply chains are derived from literature and researched applying comparative research methodology.

Rogers (1983) and Tornatzky and Fleischer (1990) state leading models in literature regarding innovation, in particular in the context of technological innovation.

The term 'innovation' can be derived from the Latin word "novus" or new. In dictionaries, the term is alternatively defined as "the introduction [of] something new" or "a new idea, method, or device".[49]

Tornatzky and Fleischer (1990) use the term 'innovation' in both senses and conclude the definition of technological innovation as following:

"Technological innovation involves the situational new development and introduction of knowledge derived tools, artefacts, and devices by which people extend and interact with their environment."[50]

The author focuses in this thesis on process innovation and underlying process technologies adopted as instruments to improve business processes according to the differentiation between product and process (technological) innovation as stated by Tornatzky and Fleischer (1990).[51]

The author applies innovation in relation to supply chains as a new way of performing supply chain management supported by enabling technologies.

Based on the following literature review of previous researches regarding innovation and its processes and impact factors, the author of this thesis derives a novel set of managerial impact factors for innovation in inter-organizational supply chains.

The author identifies the model constructs by a literature review covering all studies published to date in main international management and supply chain / logistic journals. Relevant findings and determinants from previous studies are presented. In the following, the author derived those factors that proved to be relevant drivers in previous studies and integrate them in the research model of this thesis.

Sharma et al. (2007) researched factors of analyse of adoption and diffusion of innovation focusing on two factors: strategic choice rationale, including organizational readiness, technology and external environment factor, and institutional rationale, including thee inter-organizational pressure factors.[52]

[49] cf. Rogers (1983), p. 11
[50] Tornatzky and Fleischer (1990), p. 11
[51] cf. Tornatzky and Fleischer (1990), p. 20-21 and Cooper and Zmud (1990), p. 136
[52] cf. Sharma et al. (2007), p. 3758

Kimberly and Evanisko (1981) research in a comparative analysis both technological and administrative innovations and state three predictors of innovation: individual, organizational, contextual variables.[53]

Patterson et al. (2003) focus their research regarding supply chain technology adoption/ implementation to key organizational and environmental factors including organizational size, decentralized organizational structure, organizational performance, supply chain strategy integration, inter-organizational factors (transaction climate, supply chain member pressure), and environmental uncertainty.[54]

Wen et al. (2009) identify four discriminating factors for RFID technology adoption: environment, organizational, technology and product factor. Additional factors are identified for future research.[55]

Kwon and Zmud (1987) review prior innovation research and classified variables that potentially influence technology adoption into five broad categories: individual, structural / innovation-related, technological, task-related and environmental characteristics.[56]

Scuploa (2003) studies the adoption of a new technology by investigating three perspectives: environmental, technological and organizational.[57]

Kim and Garrison (2010) use three factors – organizational needs, perceived factors such as cost and benefits and organizational readiness – for research a technology implementation process.[58]

Tornatzky and Fleischer (1990) frame the context of innovation decision making by three factors: external task environment, technology and organization.[59]

Zailani et al. (2010) define three factors – environment, organization and technology factor – and six determinants for the adoption of a new technology: customer and competitor pressure, government support, organizational readiness, size of organization, cost of the technology and perceived risks of technology.[60]

Wong et al. (2011) research the impact of inter-organizational information integration on business performance in supply chain management two main variables: external business environment conditions including munificence and uncertainty next to operating characteristics including product type and product complexity.[61]

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[53] cf. Kimberly and Evanisko (1981), pp. 695
[54] cf. Patterson et al. (2003), pp. 97
[55] cf. Wen et al. (2009), pp. 25
[56] cf. Kwon and Zmund (1987), p. 233
[57] cf. Scuopla (2003), pp. 63
[58] cf. Kim and Garrison (2010), p. 391
[59] cf. Tornatzky and Fleischer (1990), p. 153
[60] cf. Zailani et al. (2010), pp. 354
[61] cf. Wong et al. (2011), p. 169

Sabbaghi and Vaidyanathan (2008) research effectiveness and efficiency of RFID technology in supply chain management and apply four set of factors: supply chain management process, technology value, internal factors as well as external factors of the firm.[62]

For the adoption of RFID technology in the supply chain, Brown and Russell (2007) work out three categories of factors: technological, organizational and environmental factors. Chang et al. (2008) use innovation of technology, organizational and industry environment.[63]

Cheng et al. (2014) assess the inter-organization innovations performance in supply chains by two factors, information technology infrastructure flexibility and institutional orientation.[64]

Quetti et al. (2012) apply four main factors - external environment, organizational readiness, perceived benefits and supply chain readiness - for considering the antecedents of RFID adoption in inter-organizational supply chains.[65]

Kim and Lee (2008) carve out three factors for affecting the inter-organizational information flow: organizational structural, technical, managerial and environmental characteristics.[66]

Frambach and Schillewaert (2002) consider as determinants of innovation adoption on organizational level perceived innovation characteristics, adopter characteristics as well as environmental influences, social network and supplier marketing efforts.[67]

Premkumar and Roberts (1999) describe the impact of a new technology in businesses in a set of three antecedent factors: innovation, organizational and environmental characteristics.[68]

Cragg and King (1993) highlight the motivators and inhibitors of information technology on organizational performance and define determines for the stated research above.[69]

Banerjee and Golhar (1994) focus in their research the of inter-organizational information flow on customer, communication, peer pressure, productivity and cost related factors while Angeles et al. (2001) rank 25 factors carved out from literature.[70]

Further authors focus on certain issues of supply chain management, such as supply chain visibility and the ease of information sharing, and develop special research determines.[71] For some factors, different terms are given. Factors, which are not included in this research, can be distinguished and described as following:

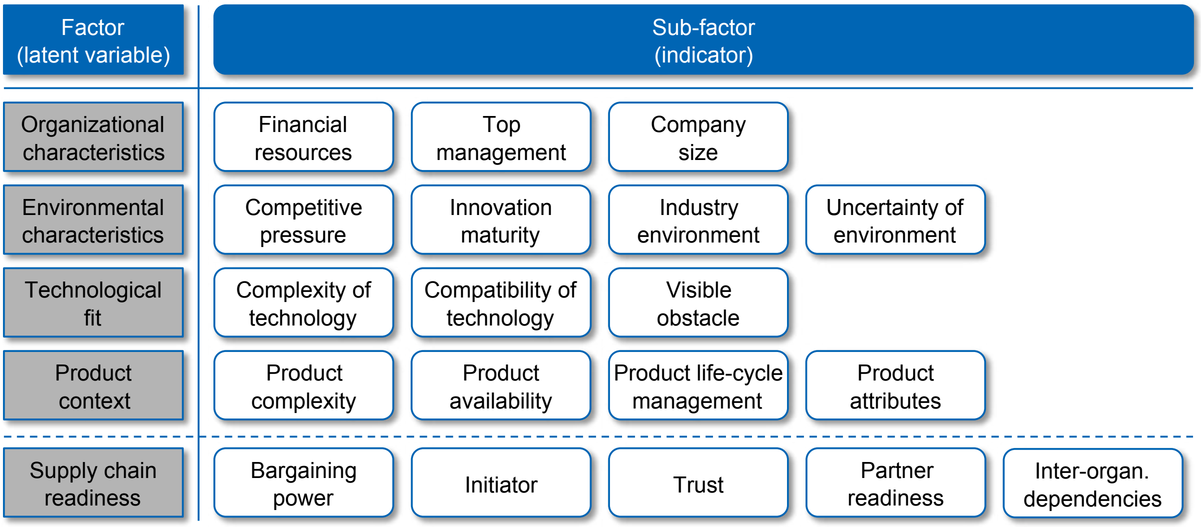
- Mimetic factors, e.g. status pressure, emulation effects / sociological dynamics, image.

[62] cf. Sabbaghi and Vaidyanathan (2008), p. 79
[63] cf. Brown and Russell (2007), pp. 252 and Chang et al. (2008), p. 204
[64] cf. Cheng et al. (2014), p. 175-176
[65] cf. Quetti (2012), pp. 317
[66] cf. Kim and Lee (2008), pp. 265
[67] cf. Frambach and Schillewaert (2002), pp. 165
[68] cf. Premkumar and Roberts (1999), pp. 470
[69] cf. Cragg and King (1993), pp. 53
[70] cf. Banerjee and Golhar (1994), p. 69 and Angeles et al. (2001), pp. 333
[71] cf. Condea (2011), p. 6, Upton and McAfee (1996), p. 129, and Igbaria et al. (1995), pp. 90

- Normative factors, e.g. industry and trade associations, incentives, supervisor, privacy (single factor in business to private end-customer researches), law and regulations.
- Coercive factors, e.g. regulatory pressures, laws.

Moderating factors are mentioned in some researches. Others do not differentiate in a moderating role of a particular factor and research only single or a framework of discriminating factors.[72]

In this thesis and in the focus of today's challenges as well as future concepts of supply chain management, the author arranges a novel construct of managerial impact factor for supply chain innovation, which influence the active management of processes, organizational structures as well as enabling technologies for actively manage the financial, information and material flow of supply chains.



Source: derived by author from Patterson et al. (2003), p. 98, Scuopla (2003), p. 64, Premkumar and Roberts (1999), pp. 470 Kim and Lee (2008), pp. 265, Quetti et al. (2012), pp. 317, Zailani et al. (2010), p. 357, Chang et al. (2008), p. 204, Frambach and Schillewaert (2002), p. 165, and Sabbaghi and Vaidyanathan (2008), p. 79

Figure 2. **Factors for innovation in inter-organizational supply chain management**

In the following and also presented in a schematic overview in figure 2, the author of this thesis introduces the relevant determinants for the organization's decision to adopt and implement technological innovation in intra-organizational supply chain: 'organizational characteristics', 'environmental characteristics', 'technological fit', 'product context' and 'supply chain readiness'. The measurement scale for each indicators of each latent variable will be derived from literature in chapter 2.5.3.

[72] cf. Wen et al. (2009), p. 30-31, Karahanna et al. (1999), p. 188, Quetti et al. (2012), pp. 317, Teo et al. (2003), pp. 21, Prasad and Sounderpandian (2003), pp. 242, and Sharma et al. (2007), pp. 3758

1.4.2. Organizational characteristics

The factor 'organizational characteristics' in the process of supply chain innovation refer to the internal resources of the company that can be assigned to support technological innovation.

Recent studies indicate internal resources of a single enterprise impact technological innovation. In contrast to a supporting effect on the adoption process, a lack of internal organizational readiness of a single enterprise may limit the inter-organizational innovation potential for all partners along the supply chain, for example by hindering the feasibility of an innovation initiative.

Literature highlights three indicators to determine the factor (internal) 'organizational characteristics':

- Financial resources
- Top management
- Company size

Financial resources allow investing in new technologies and absorbing the associated risks and are therefore one factor for technological innovation. Financial resources are needed to invest in the implementation of technological innovation covering all cost for gaining knowledge regarding the new technology, training of employees, and for the organization integration.[73] One specific characteristic of most inter-organizational implementations of innovation is the unequally distribution of resulting benefits and initiative financing. In addition, financial readiness is not equally distributed among supply chain partners.[74] Overall it can be stated, that inter-organizational innovations request a supportive factor such as 'financial resources' as a base for implementing innovation.

Top management support, such as managerial enthusiasm, has been identified as one important factor for innovations. Teo et al. (2003) highlight in their research of inter-organizational innovation adoption the role of the organizational decision makers as an influencing factors.[75]

Company size is one of the most researched factors in decision-making theory. However, literature still includes some disagreement about the direction of its relationship.

Kimberly and Evanisko (1981) state that a positive relationship has been found reasonably consistently at empirical level between organizational size and innovation level. A positive impact of organizational size to innovation behaviour can be explained by two underlying

[73] cf. Quetti et al. (2012), pp. 320 and Robey et al. (2008), p. 506

[74] cf. Fichman (2004), pp. 317 and Iacovou et al. (1995), p. 48

[75] cf. Brown and Russell (2007), p. 254, Premkumar and Ramamurthy (1995), p. 311, Teo et al. (2003), p. 40-41, and Cragg and King (1993), p. 53

reasons. First, critical mass is stated as an underlying reason. An increasing organizational size creates a critical mass, which justifies the acquisition of particular innovations. The bigger companies may simply be better able to afford the innovation. Secondly, organizational size necessitates adoption behaviour. The increased size of organizations may create uncertainty that demand innovative behaviour. [76]

Alternatively, other authors indicate smaller organizations are more likely to be innovative due to the flexibility afforded by smaller size and fewer levels of bureaucracy.[77]

In this thesis, the indicator 'company size' is supposed having a supporting effect on technology innovation due to the resources – e.g. financially, knowledge, bargaining power – needed to implement innovations in an inter-organizational context.

1.4.3. Environmental characteristics

In numerous innovation studies, a variety of (external) 'environmental characteristics' are mentioned including economic condition, global competitiveness, transaction climate, industry concentration, and environmental uncertainty for decision making of innovation adoption.[78]

The author highlights four indicators to determine the factor (external) 'environment characteristics':

- Competitive pressure
- Innovation maturity
- (Supplier's) Industry environment
- Uncertainty of environment

Competitive pressure is highlighted in several studies as an influencing factor and becomes even more evident if the innovation directly affects the competition in the industry. Scuopla (2003) identify in his study external pressure from business partners, both suppliers and customers, and competitors as one issue influencing the adoption of technological innovation.[79] In literature, the factor 'competitive pressure' is frequently mentioned in the retail business, in which large retailers, such as Wal-Mart and Metro, are often keenly aware of ongoing innovation initiatives of competitors. Whereas the retail business focuses in particular on reducing cost, the automotive industry focuses also on increasing supply chain effectiveness in their highly integrated just-in-time delivery supply chain management

[76] cf. Patterson et al. (2003), p. 98 and Kimberly and Evanisko (1981), p. 699-700
[77] cf. Brown and Russell (2007), p. 254 and Patterson et al. (2003), p. 99
[78] cf. Patterson et al (2003), p. 101 and Premkumar and Roberts (1999), p. 471-472
[79] cf. Scupola (2003), p. 64

process. Chang et al. (2008) even distinguish competitive pressure between the sub-constructs of pressure from transaction partners and the degree of competition in the marketplace.[80]

Innovation maturity and the underlying life-cycle phase of an innovation are usually critical for the innovation's adoption and spread. Rogers (1983) states a diffusion process and stages of innovation. The stages include the earlier adopters, take-off and the later adopters phase.[81] The maturity and underlying life-cycle phase of the identified innovation (see also next chapters) need to be sufficient to implement these innovations for reaching the concept of 'Industrie 4.0'. The experience gathered in other industries, e.g. retail and automotive, might indicate a positive relationship of the actual innovations phase and the impact on supply chain performance. On the other side, a perceived immaturity of these innovations might increase the level of perceived risk and uncertainty of the decision. Under this last permission, a low perceived innovation maturity might inhibit its adoption and spread.

Industry environment is used in previous researches as one determining factor of innovation adoption. Chang et al. (2008) focus on supplier's industry environment and state the hypothesis, that it might affect technological adoption in the logistic industry. Chang et al. (2008) reference to the findings of Gatignon and Robertson (1989), who state three items of the supplier's competitive industry environment - vertical coordination with the customers, supplier's initiative and reputation of the industry. Quetti et al. (2008) apply a more general view and reference the factor 'industry environment' to the industry's characteristics in which a supply chain operates.[82]

The author of this thesis uses the more general industry characteristics in the factor 'industry environment'. Examples are the presence of influencing industry associations, lobby groups, pilot projects and other previous documented experiences in the industry's supply chain. In this thesis, the influence directly from suppliers and logistic providers within the supply chain of the utility industry is classified in a specific factor – 'supply chain readiness'.

Uncertainty of environment as perceived by the decision maker might also affect innovation adoption decision. Patterson et al. (2003) apply environmental uncertainty as one variable of environment factor for technological innovation. Reasons or sources for this kind of perceived uncertainty by the decision make are the unreliability of supplier's delivery quantities and quality, unpredictable demands and rapid shifts in production processes. Especially in the German utility industry, the actually ongoing transmission of electricity generation from fossil to renewables energy source is a major source of the industry's uncertainty (see also later chapters). Walton and Miller (1995) define uncertainty in general as

[80] cf. Brown and Russel (2007), p. 254-255, Patterson (2003), p. 101, and Chang et al. (2008), p. 204-205
[81] cf. Rogers (1983), p. 11 and Quetti (2012), p. 318
[82] cf. Gatignon and Robertson (1989), pp. 36, Chang et al. (2008), p. 204-205, and Quetti (2012), p. 318

the non-existence of information for the organization's decision makers. Patterson et al. (2003) summarize mechanism to overcome imperfect information, e.g. by the approach from Truman (2000) to promote, advance and strengthen coordination between supply chain members. According to literature, this thesis uses 'environmental uncertainty' as one variable for innovation adoption in inter-organizational supply chain management.[83]

Next to 'environmental factors', the author of this thesis also identifies technological aspects - related to managerial and administrative levels in business organizations – as relevant within this research.

1.4.4. Technological fit

The factor 'technological fit' is measured by an item scale that evaluates the innovation at the administration department in the company. In contrast to other studies, all technological variables are combined in this thesis under the factor 'technological fit'.
Literature highlights three indicators to determine the factor 'technological fit':

- Complexity (of technology)
- Compatibility (of technology)
- Visible obstacle

Complexity of an innovation is defined according to Karahanna et al. (1999) as the degree to which using a particular system is free of effort. Kwon and Zmud (1987) relate complexity of an innovation to the degree of difficulty, user experience in understanding and using an innovation. Rogers (1983) defines complexity as the degree to which an innovation is perceived as difficult to understand and use. Literature mentions lack of skills and knowledge to be a primary aspect behind efforts to resist innovation. If a new (technological) innovation is perceived as complex, decision makers might involve this factor as an obstacle in the decision-making process.[84]

Compatibility of systems is a major basis for technological innovation. The importance of innovation's compatibility is frequently mentioned as a factor explaining the success of innovation efforts. Kwon and Zmud (1987) state that this factor is related to an innovation's organizational fit as its impact on individual's attitude regarding change. Brown and Russell (2007) refer the term 'compatibility' to the degree to which a technology is perceived to be consistent with an organization's strategic intent, infrastructure, practices and needs. In this thesis, the factor 'compatibility' within inter-organizational innovations is used in reference to

[83] cf. Patterson et al. (2003), p. 102-103, Walton and Miller (1995), p. 121, Chang et al. (2008), pp. 205, Truman (2000), p. 213, and Kwon and Zmud (1987), p. 240
[84] cf. Karahanna et al. (1999), p. 188, Kwon and Zmud (1987), p. 237-238, Rogers (1983), p. 15, Chang et al. (2008), p. 206, and Kim and Garrison (2010), p. 396

the changes requested by implementing a new supply chain technology. Some researchers use this aspect only in technological context. In this thesis, this variable is assigned to the factor technology with interpretation by e.g. Brown and Russell (2007), Quetti et al (2012) and Iacovou et al. (1995) in both technical and organizational compatibility.[85]

Visible obstacle of technological aspects impacts the spread of innovations in inter-organizational environments.

In literature, the variables 'complexity' and 'compatibility' are frequently used for assessing the factor technology for decision making of adopting a technological innovation. Regarding further research variables, researcher use different kind of scales. In relation to the research topic of this thesis, the sub-factor 'visible obstacle' of technological aspects is identified for (technological) innovation adoption covering different sub-variables.

Chau and Tam (1997) state that the decision maker's understanding of the obstacle of technical aspects affects the adoption of innovation. Chang et al. (2008) apply this finding in their research for adoption of an innovative technology in the logistic industry.[86]

Relevant obstacles for the adoption of innovative technology in inter-organizational supply chains are information system infrastructure and mutual standards.

Information system infrastructure, also often called 'sophistication', regards to the technological infrastructure (hardware and software), people and expertise available to support technological implementation and integration of innovations. Camarinha-Matos et al. (2009) identify the availability of a flexible and configurable base infrastructure as one of the main requirements for the practical implementation.[87]

Mutual standard in form of international standards, norms and regulations are important for the adoption of technological innovation in more complex supply chain collaborations. These mutual standards ensure the quality of transmission and reliability of an enabling technology.

One aspect with an increasing importance refers to privacy consideration regarding to a new supply chain management technology. Due to the researched supply chain characteristic (supply chain collaboration between enterprises without any private end-customer involved), this aspect is identified as less important.

[85] cf. Pfeiffer (1992), pp. 54, Kwon and Zmud (1987), p. 237, Brown and Russell (2007), p. 253, Karahanna et al. (1999), p. 188, and Iacovou et al. (1995), p. 466

[86] cf. Chau and Tam (1997), p. 9, Chang et al. (2008), p. 206-207, and Sharma et al. (2007), pp. 3758

[87] cf. Quetti et al. (2012), p. 320-321, Sharma et al. (2007) pp. 3758, Kim and Garrison (2010), p. 395, and Camarinha-Matos et al. (2009), p. 58

1.4.5. Product context

Only very few researchers include the factor ‘product characteristics’ in their models of determinates for innovation in the maintenance and material management area. The author identifies the characteristics of products in this research as one central determinant for innovation in inter-organizational supply chain management.

Product characteristics vary significantly in industry sectors with a high ratio of maintenance work to proceed bulk materials, e.g. in the chemical or the electricity generation industry. Upstream bulk materials, such as preliminary chemicals or the energy carriers hard coal, natural gas and lignite, are proceeded with specific attributes: high degree of automation, complex process technology, capital-intensive plants and equipment, bulk production respectively transformation as preliminary energy carriers. These production attributes require a flexible supply chain for mainly required maintenance materials and repair labour.

Deducted from literature, four indicators for determining the factor ‘product context’ can be named and will be applied in this thesis:

- Product complexity
- Product availability
- Product life-cycle management
- Product attributes

Product complexity is one determining factor for innovation in inter-organizational supply chain management. Product complexity is referring to the number of products and suppliers. A higher fluctuation in product characteristics and number of suppliers requires additional efforts for implementing (technological) innovation in intra-organizational supply chain management.

Product availability is mostly the basis for effective and efficient business processes and one driver for (technological) innovation. Product availability is a key factor in the maintenance, repair and overhaul processes. Especially in the electricity generation, shortage costs (might result in the unavailability of a generation unit) are main cost drivers. Gärtner (2011) review research literature and developed a decision supporting calculation model for the determining the service level of an article, which should be achieved by considering the shortage costs, and opposing cost of stock keeping. Alscher (1981) reasons that in practice service levels are preferred to shortage costs due to existing limitations in practice.[88] An innovation in the management of these materials might ensure or even increase the product availability and minimize the risk and costs of shortage costs.

[88] cf. Gärtner (2011), pp. 30, Alscher (1981), p. 73, and Aastrup and Kotzab (2010), p. 151

Product life-cycle management is a key task in maintenance, repair and overhaul processes and therefore one determinant for (technological) innovation. A SCM innovation might support or add new services to the product life-cycle management. Due to capital intensive and complex production facilities, some spare-parts are – internally or externally - repaired and re-used several times. Literature falls short of researching the determining factors and effects of (technological) innovations in production and supply chain management. Capital-intensive production facilities, especially the newly constructed power plants in recent years, apply technological innovation for process management and e.g. the clearance management during maintenance work. Production and maintenance processes use advanced processes and underlying technologies for relevant plant component without being aligned with supply chain management.[89] Applying these (technological) innovations also in supply chain management might support the handling of materials such as the product-life cycle management and the underlying documentation and handling of assets.

Product attributes have a high impact on the benefits of the adoption of new SCM technologies. Consumables, especially throwaway products, and low-value products are less applicable for a technological innovation investment. In capital-intensive production facilities, the value of an item is partly used to access its strategic relevance and criticality. The turnover rate in connection to the overhaul intervals are normally also applied in this context. Low value items consumed in production and maintenance processes in every day practice are less relevant due to low shortage costs and missing product-lifecycle management. In contrast, high value, strategic and critical items in production and maintenance processes might show a higher relevance for (technological) innovation in inter-organizational supply chain management. Batch sizes might need to be defined for adopting of innovation.[90]

In summary and in contrast to most previous researches, the author identifies the factor 'product context' as a relevant managerial impact factor of innovation in inter-organizational supply chains.

1.4.6. Initiator 'supply chain readiness'

In this study, 'supply chain readiness' is stated as an initiator for innovation in inter-organizational supply chains and the resulting increase of supply chain performance. Wen et al. (2009) state that a real advantage of technological innovation can only be achieved in the

[89] cf. „Warenwirtschaft: RFID Im Materialmanagement" (2008), p. 28-29
[90] cf. Cooper and Zmud (1990), p. 130-131

supply chain if its members are collaborating.[91] This collaborative characteristic of a supply chain is stated as an initiator of the positive effects of technological innovation.

It might be also argued to define supply chain readiness as a multiplier for the innovation adoption and supply chain performance. Therefore, supply chain readiness needs to be researched regarding a potential correlation with the managerial impact factors of adoption of supply chain innovation as well as supply chain effectiveness and efficiency. The author of this thesis identifies the factor 'supply chain readiness' and the following five indicators as an initiator for the adoption of supply chain innovation in inter-organizational supply chain. The adoption of the innovation, including its managerial impact factors, is then relevant for a change of supply chain performance.

Literature highlights five indicators to determine the factor 'supply chain readiness':

- Bargaining power
- Initiator
- Trust
- Partner readiness
- Inter-organizational dependencies

Bargaining power of some market actors influence the diffusion process of innovation between supply chain partners. The bargaining power can slow or accelerate an adoption process. Iacovou et al. (1995) describe the use of promotional efforts and non-coercive influence tactics to promote innovation adoption. Iacovou et al. (1995) state that in many cases, diffusion of innovation is delayed because the managers of small organizations fail to perceive the innovation's benefit. To overcome these restraints, they define three tactics though which a supply chain partner can impose its willingness. The first tactic is defined as promises meaning that supply chain members with more power can reward other member's adoption of the innovation. Secondly, recommendations by which supply chain members with more power can use information about the innovation's benefits to push innovation. A third tactic is called threats by which supply chain members with more power can impose other supply chain members. Examples for this factor and the stated tactics can be found in the retail and automotive industry.[92]

Initiator is one role and consequently one factor in the innovation adoption process. Literature combines the presences of an initiator as facilitator of innovation. Typically, during the implementation of an innovation, one company initiates adoption and pressure others in

[91] cf. Wen et al. (2009), p. 25
[92] cf. Iacovou et al. (1995), pp. 480 and Quetti et al. (2012), p. 322-323

the supply chain to adopt in order to standardize certain innovative approaches and to maximize the innovation's benefits.

As one example for the relevance of the sub-factors 'bargaining power' and 'initiator', the retail industry and the behaviour of key market actors, such as K-mart and Wal-Mart, is well documented in research literature. Wal-Mart has pressured its suppliers to adopt innovation, e.g. EDI and later RFID technology.[93]

Trust is essential for the decision to adopt innovation with other supply chain partners. Patterson et al. (2003) refer to social exchange theory and state that relationship and social factors between supply chain members influence the organization's activities and transactions. Literature uses the term 'transaction climate' in reference to these relationships and social elements between organizations. The level of trust and faith in the inter-organizational dimension are key elements of the transaction climate and identified as key elements for the adoption of innovation. A high level of trust and commitment of the supply chain partners is required for overcoming the risks associated with an innovation, such as leaner processes with less check-ups and supervision.[94]

Partner readiness is an important variable for the adoption of innovation between supply chain members. Some authors focus only on the readiness within the organization whereas in this thesis, the focus is in on the readiness between the companies.

Chewlos et al. (2001) differentiate the necessary conditions for the adoption of innovations. The ability to adopt a technological innovation in the inter-organizational dimension refers to the integrated technological infrastructure between the supply chain partners. In addition, the trading partners must be motivated to adopt the innovation, which refers in this thesis to the willingness for innovation. Some authors also add a cultural dimension to determine the willingness. Therefore the sub-factor 'partner readiness' refers to the ability and willingness for the adoption of innovation among supply chain members.[95]

Inter-organizational dependencies, which already exist between the supply chain members, influence the adoption of innovations in the cooperation between the organizations. Some researcher focus on the vertical linkages between firms related within franchises and subsidiaries. Strong linkages to the franchisor or parent company facilitate the transfer of technologies and innovations. Next to these specific relation within franchises and subsidiaries, existing inter-firm contacts and business relationships influence the connection between organizations. The dependencies are strongly influenced by frequency, ratio and

93 cf. Patterson et al. (2003), p. 101-102, Quetti et al. (2012), p. 323, Brown and Russell (2007), p. 254, and Karahanna et al. (1999), pp. 188

94 cf. Patterson et al. (2003), p. 101-102 and Premkumar and Roberts (1999), p. 481

95 cf. Chwelos et al. (2001), p. 316, Brown and Russell (2007), p. 254, Patterson et al. (2003), p. 100-101, Wen et al. (2009), p. 25, and Quetti et al. (2012), p. 323-324

duration of collaboration. In combination to the stated sub-factors bargaining power and initiator, the example of the retail industry and Wal-Mart's initiative to push innovation with their suppliers illustrates the factor 'inter-organizational dependencies' well.[96]

The measurement model's factors of the depending variable supply chain performance are stated in the following. The detailed measurement scale of the self-completion questionnaire survey is present later in the research design.

1.4.7. Supply chain effectiveness and efficiency as depended measurement indicators

Next to the deducted managerial impact factors of innovation, the value of innovation on supply chain management is measured by effectiveness and efficiency according to the research models of e.g. Zelbst et al. (2012), Chopra and Meindl (2013) and Sabbaghi and Vaidyanathan (2008).[97]

In an economical perspective, long-term successful business organizations have to be both effective and efficient. Drucker states effectiveness as doing the right things and efficiency as doing things right.[98] In relation to general system theory, Hofer and Schendel (1978) define effectiveness as the "degree to which the actual outputs of the system correspond to its desired outputs", and efficiency as the "ratio of actual outputs to actual input".[99]

The author theorizes (supply chain) efficiency as the organization's ability to produce goods and services at relatively low cost to customers, which is based on the organization's capability to eliminate waste and fully utilize resources. Effectiveness, also related to supply chain management, is the organizations ability to satisfy customer needs. Hofer and Schendel (1978) seek effective organizations to be concerned with activities that promote effectiveness. Hunt and Duhan (2002) view effectiveness seeking as striving to deliver superior value to the customer.[100] For example, enabling technologies in supply chain management have to be both effective by identifying logistic items on requested response rates and efficient in terms of evaluating costs and benefits. Banks et al. (2007) state, "in supply chain applications, first-pass accuracy is important to maintaining a high level of efficiency"[101].

The author applies effectiveness in inter-organizational supply chains in this research to the supply chain's ability to deliver the right material at the right time in the right quantity and

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[96] cf. Premkumar and Roberts (1999), p. 472, Chang et al. (2008), p. 205, Quetti et al. (2012), p. 324, and Kwon and Zmud (1987), p. 241

[97] cf. Chopra and Meindl (2013), pp. 50, Zelbst et al. (2012), p. 340, and Sabbaghi and Vaidyanathan (2008), p.79

[98] cf. Drucker (1955), p. 117 and Drucker (1963), p. 54

[99] cf. Hofer and Schendel (1978), pp. 2

[100] cf. Hunt and Duhan (2002), p. 100 and Hofer and Schendel (1978), pp. 2

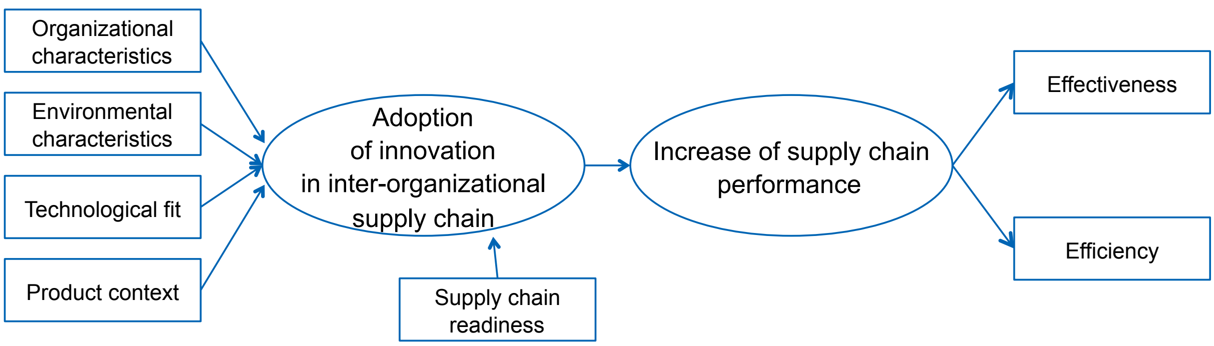
[101] Banks et al. (2007), p. 22

quality at the right place. Efficiency is related to the supply chain partners' ability to achieve that at low cost.

The evaluation of the innovation's impact on supply chain performance will carried out in this thesis by combining measurement scales of supply chain effectiveness and supply chain efficiency. Rogers (1983) highlights as one characteristic of technological innovation the relative advantage, which is defined as the "degree to which innovation is perceived as better the idea it supersedes".[102] Studies on technology adoption indicate that technology adoption is positively influenced on adopter's awareness and positive attitude toward the technology benefits.[103] In this thesis, the evaluation of the innovation's impact on supply chain performance will carried out in this thesis by combining measurement scales of supply chain effectiveness and supply chain efficiency.

1.4.8. Research model combines managerial impact factors for supply chain innovation

As stated before, systems theory in combination with utility theory can be applied to supply chain management and its integration. Supply chains are characterized as systems as defined by systems theory. By changing factors and parameters in one subsystem - such as implementing a new technology within supply chain integration - the whole system is affected by this change. Utility theory as one aspect of decision-making theory for choice under uncertainty deals with the company's utility / usefulness for its decision makers whether to utilize an innovation to promote or to increase performance.



Source: compiled by author

Figure 3. **Research model**

The research model in this thesis, as stated by the author in the figure 3 in format of the inner (structural) and outer (measurement) model within structural equation modelling, is served to

[102] Rogers (1983), p. 15 and cf. Cragg and King (1993), p. 53
[103] cf. Sigala (2007), p. 24

investigate the influential factors for the adoption of innovation in inter-organizational supply chains (independent variable) that may result in an increase of supply chain performance (dependent variable).[104]

The relationship of exogenous and endogenous variables, including its indicators, is also stated in the measurement model (outer model) of the structural equation model in appendix 3 and will be explained in more detail later in following chapter. The exogenous latent variables are ‘organizational characteristics’ (Org), ‘environment characteristics’ (Env), ‘technological fit’ (Tec) and ‘product context’ (Pro). ‘Supply chain readiness’ (Scr) is stated as an inductive latent variable on adoption of innovation. The endogenous latent variables are ‘supply chain effectiveness’ (Scs) and ‘supply chain efficiency’ (Sys).

The author derives in the first chapter a new construct of managerial impact factors for innovation in inter-organizational supply chains. The author applies the stated research model by the following research methodology and design. In addition to the model’s empirical application within the selected German electricity power generation industry, the research model is combined with comparative research design for examining the impact of two relevant innovative enabling technologies on supply chain performance in inter-organizational supply chains.

[104] cf. Buckler (2001), p. 31, Urbach and Ahlemann (2010), p. 10, and Nitzl (2010), p.4

2. Sequential Triangulation combined with Comparative Research for Testing Managerial Impact Factors within Inter-Organizational Supply Chain Management

In part two of this thesis, the research methodology and the research design will be outlined. First, the author deducts from actual research methodology approaches the applied casual research method including falsification of hypotheses as well as sequential triangulation. Underlying quality criteria and ethical standards of this research are introduced.

Secondly and derived from the need for further supply chain integration and collaboration between the supply chain members, two enabling technologies for the comparative research method are stated according to actual research. It will be focused on the state of the art of two Auto-ID technologies, RFID and two-dimensional bar code technology, covering evaluation models and main benefits and costs within the concept of the Internet of Things.

Next, the approach taken for this study regarding the German business sector of electricity power supply and in particular the electricity power generation without transmission is explained and its influences on the research design is deducted.

On this basis, the research design including the empirical data collection process and the measurement scale is derived from literature for each the semi-structured of interviews with experts as well as the self-completion questionnaire survey.

2.1. Casual research applying sequential triangulation and comparative method

In chapter 2.1., the research methodology of casual research including falsification of hypotheses, sequential triangulation and the comparative research method will be outlined, followed by a presentation of applied underlying quality and ethical standards.

2.1.1. Research methodology adopted for inter-organizational supply chain innovation

The research approach can be described as causal research. In contrast to exploratory research and its approach of gathering preliminary information that will help define problems and suggest hypotheses as well as descriptive research and its approach of describing characteristics of a population or phenomenon being studied, in thesis casual research and its approach of testing hypotheses about cause-and-effect relationships is applied.[105]

[105] cf. Brians et al. (2011), p. 76, Nitzl (2010), p. 4, and Buckler (2001), p. 31

The problem of induction or the so-called underdetermination of theory covers the fact that it will never be possible, given a coherent set of facts, to arrive by induction at a single, ineluctable theory. This difficulty led philosophers, such as Karl Raimund Popper, to reject the notion of verification in favour of the notion of theory falsification.[106] According to Doyal (1993), a former student and colleague of Popper, certainty or even a high probability in knowledge was an illusion for Popper because given the universal claims of scientific theories we can never prove them on a basis of our particular experience.[107]
For this reason, Popper's philosophy of falsification is applied in this thesis to intentionally test hypotheses against evidence to the limit and to avoid being dictatorial in research.
The hypotheses are stated according Popper's view of disconfirming one's hypothesis or existing view. Therefore, they are formulated in a way most easily exposed to possible refutation. The advantage is that only one refutation is sufficient to falsify a theory.[108]

In research philosophy, it can be distinguished between positivism, which adopts a clear quantitative approach to investigate phenomena, and post-positivism/interpretivism, which aims to describe and explore an in-depth phenomenon from a qualitative perspective.[109]
The research method used in this thesis can be called mixed research method. According to Johnson et al. (2007), mixed method research can be defined as following:

"Mixed method research is the type of research in which a researcher or a team of researchers combines elements of qualitative and quantitative research approaches for a broad purpose of breadth and depth of understanding and corroboration."[110]
This research technology is also named multimethod research, integrative research and triangulated studies.[111] Post-Positivist approaches gave way to combine qualitative and quantitative methods, which furthermore can be described as critical research.[112]

The author of this thesis intends to incorporate the advantages of both methods by using the mixed method research method. The bias inherent in any singular method will be cancelled out when used in conjunction with other methods. The results of the integrative research approach will therefore be the convergence upon the truth about some social phenomena.[113]
The author of thesis also highlights that this thesis has to been seen in combination to other studies of the research problem - the so-called triangulation approach of research. By using

[106] cf. Guba and Lincoln (1998), p. 199
[107] cf. Doyal (1993), pp. 6
[108] cf. Popper (1935), pp. 40 and Easterby-Smith et al. (2002), p. 51
[109] cf. Crossan (2003), p. 46 and Collis and Hussey (2009), pp. 58
[110] Johnson et al. (2007), p. 123
[111] cf. Johnson and Onwuegbuzie (2004), p. 24
[112] cf. Letourneau and Allen (1999), p. 624
[113] cf. Denzin (2009), p. 14-15, 26-27 and Sarac et al. (2010), p. 89

triangulation researching a single phenomenon, the personal biases of investigators - including the author of this thesis - should be avoided and the deficiencies of a single-investigator, single-theory or single method study should overcome to promote greater confidence in the observed findings.[114]

Furthermore, two types of methods triangulation can be differentiated: simultaneous and sequential. According to Morse (1991), simultaneous use of qualitative and quantitative methods limits the interaction of the two sources during the data collection stage of the research process. Sequential triangulation is utilized when the results of one approach are necessary for planning the next stage of data collection by using another research method.[115] The author of this thesis uses multimethod research[116] in a sequential way.

In the first stage of the data collection, qualitative research is used to identify the actual stage of research. In addition to a theoretical analysis of literature, semi-structured interviews with experts are carried out.

Based on the results and findings of the first stage, a data collection using quantitative research methods is planed and executed. A questionnaire survey within the defined basic population tests the stated hypotheses in order to answer the research question.

With reference to Stichweh's (2011) definition of systems, the author of this thesis uses comparative research methodology for evaluating relevant enabling technologies for supply chain innovation in inter-organizational supply chains aiming to answer the stated research question. Durkheim (1938) insists that "comparative sociology is not a particular branch of sociology; it is sociology itself, in so far as it ceases to be purely descriptive and aspires to account for facts".[117] Comparative research refers to "studies […] that involve comparisons of […] phenomena in two or more societies".[118] Oyen (1990) notices, "no social phenomenon can be isolated and studied without comparing it to other social phenomenon", whereas Börtz and Döring (2006) highlights the central role of comparisons for researching a certain research topic.[119]

In this thesis, the author uses comparative method in the combination with quantitative, variance-theory research in contrast to mostly case-orientated quantitative comparative methods. Taking into account the methodological problems of comparative research as stated by Mills et al. (2006), the variable-oriented and therefore theory-centred approach as stated by

[114] cf. Letourneau and Allen (1999), p. 625, Collis and Hussey (2009), p. 85, and Denzin (1973), p. 301. According to Denzin (1973), triangulation can be categorized by data, investigator, theory and methodology.
[115] cf. Morse (1991), pp. 120
[116] See also Brewer and Hunter (1989), p 38.
[117] Durkheim (1938), p. 139 and cf. Hantrais (2009), p. 24-25
[118] Armer (1973), p. 49
[119] Oyen (1990), p. 4 and cf. Bortz and Döring (2006), p. 366 and Armer (1973), p.49-50

Ragin (1987) is used with the goal of producing explanations of phenomenon of the impacts of Auto-ID technology on supply chain performance while taking.[120]

For the execution of the stated research methods, the author applies the following quality and ethical criteria in this research.

2.1.2. Quality criteria and ethics of the research

Quality criteria and ethics of this research are applied by the author as following.

The author of this thesis utilises two factors as quality criteria in this research - validity (is the stated evidence valid) and reliability (is the stated evidence correct). Positivist / quantitative research method orientated studies typical apply four criteria to evaluate the quality of the performed research.[121] The four criteria are the three traditional validity aspects (construct, internal, external) and reliability, which are relevant in this thesis and are applied in previous logistic researches.

Internal validity addresses weather the independent variables – managerial impact factors - cause the dependent variable while various threats need to be considered by the researcher. On the grounds of the applied triangulation including descriptive research method in this thesis, a low requirement for internal validity can be assumed.

Construct validity concerns weather the measures assess what they purport to assess by investigation two types of validity - convergent validity and discriminant validity.

External validity concerns the generalizability of study findings, which means the ability of replication of research results in different contextual settings. The author of the thesis will determine the scope of the stated findings in the context of application the real world.

Reliability measures the ability to repeatedly yield similar results across similar situations and functions as a necessary precondition for establishing the stated validity.[122]

The author of this thesis adopts the stated criteria to measure and ensure research quality in awareness of alternative constructs. According to Kvale (2009), reliability and validity in interview settings is also ensured by for example quality criteria from Lincoln and Guba (1985), who propose two primary criteria for assessing a qualitative research: trustworthiness, covering creditability, transferability, dependability, and conformability, as well as authenticity, covering fairness, ontological, educative, catalytic, and tactical authenticity.[123]

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[120] cf. Mills et al. (2006), pp. 621, Ragin (1987), p. 54 and Rihoux et al. (2009), pp. 170. A large body of literature of comparative reserach in the social scienes has apperead, see also Ragin (1987) and Arts and Halman (1999).

[121] cf. Näslund et al. (2010), p. 338, Mentzer and Kahn (1995), p. 237, and Bryman and Bell (2011), pp. 394

[122] cf. Mentzer and Kahn (1995), pp. 238, Mentzer and Flint (1997), p. 201-202, Dunn et al. (1994), pp. 156, Ellram (1996), pp. 104, Konrad (2001), pp. 98, and Garver and Mentzer (1999), p. 35-35

[123] cf. Lincoln and Guba (1985), pp. 289, Kvale (2009), p. 244-245, and Bryman and Bell (2011), p. 394-395

Overall in this thesis, the applied research method triangulation reduces the risk of systematic distortion inherent in the use of only one method.

Ethical and moral aspects are involved and observed during the used qualitative and quantitative research methods.

The author of this thesis performs all stages of the research process on the basis and actual research standards such as the ethic codex of the German Sociological Association (GSE) and the Berufsverbandes Deutscher Soziologen (BDS), the guidelines from the American Psychological Associaiton and the Academic Ethics Codex of the University of Latvia.[124]

The author of this thesis follows in the practicing of interviewing for research purposes ethical aspects such as stated by Kvale and Brinkmann (2009) for all seven research stages - thematizing, designing, interview situation, transcription, analysis, verification and reporting.[125] In this thesis, ethical issues are especially respected while designing the interview guide, during each interview situation and the reporting. Confidentiality is here a key aspect in reporting the findings. The interviewees shared very internal and business critical information which are not written down in the interview reports but are still very useful for the author of this thesis in reviewing the actual state of the art regarding implementing supply chain innovations and underlying enabling technologies in today's supply chain management.

2.1.3. State of the art regarding supply chain management and logistics research

In recent years, several researchers examine the state of art regarding supply chain management and logistics research by analysing aspects such as the research design and methods, number of hypotheses, data sources and analysis techniques.

Sachan and Data (2005) identify empirical quantitative research design as most often applied - 37 percent - in contrast to only 2 percent of the research papers use empirical triangulation.[126] Researchers also observe an increase in direct research methods such as case studies.[127] Compared to the research of Mentzer and Khan (1995), the data analysis technique of case studies multiplied in utilization - from 3.2 percent stated by Mentzer and Kahn (1995) to 16.1 percent stated by Sachan and Datta (2005). In both literature analyses, the most applied research method is the survey technique- 54.3 percent stated by Mentzer and Kahn (1995) and

[124] cf. German Sociological Association (accessed 11.03.2015), American Psychological Association (2010), pp. 20 and pp. 231, The University of Latvia (2008, accessed 25.10.2015), Gläser und Laudel (2010), pp. 295, Collis and Hussey (2009), pp. 44, and Bryman and Bell (2011), pp. 127

[125] cf. Kvale and Brinkmann (2009), pp.63 and Brace (2013), pp. 200

[126] cf. Sachan and Datta (2005), p. 667 and Mangan et al. (2004), p. 565

[127] cf. Pedrosa et al. (2012), p. 284-285 and Sachan and Datta (2005), p. 667

34.6 percent stated by Sachan and Datta (2005) - followed by mathematical models and the category of other research techniques.[128]

The author of this thesis takes these finding into account while selecting the triangulation research method in this research.

Overall, the author of this research applies different qualitative research methods before and during the statement of the research question and the research hypotheses. The area of work within the supply chain management and procurement area in the utility business contributed to this process, next to regular visits at specialized fairs for supply chain management, e.g. LogiMat and Hannover Faire (Hannover Messe) as well as or Auto-ID Technologies, e.g. Euro ID. In addition, in interaction with the Fraunhofer Institute for Material Flow and Logistics IML in Dortmund and its research laboratories broadened the scope of this research thesis.

2.1.4. Approach taken for this research regarding German electricity generation industry

Supply chain and logistics research is influenced by economical research approaches, focusing on cost minimization and benefit/profit maximization, and behavioural research approaches, focusing on psychological and sociological aspects.[129] Stock (1997) identifies a series of further theories from other disciplines influencing logistics including information technology and computing as a cluster for automatic identification technologies.[130]

Soni and Kodali (2011) state in a critical analysis of supply chain management content in empirical research that many researchers base their analysis on focal firms - in contrast to this dissertation and the focus on an industry wide research design. A huge gap between theory building and theory verification in supply chain management is also identified which highlights the importance of theory verification - such as the impact of an innovation and its predicted impact in supply chain performance.[131]

In accordance to the stated findings of the following chapter 2.2. and the findings and implications for future research by Soni und Kodali (2011), the author of this thesis researches a broader industry segment in form of the German electricity generation industry and its underlying need for – supply chain – innovation in order to meet the upcoming cost pressure and predatory competition for each power unit in the further progress of the German

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[128] cf. Sachan and Datta (2005), pp. 669 and Mentzer and Kahn (1995). p. 242. Sachan and Datta (2005) review 442 papers published from 1999 to 2003 in the three selected academic journals. Mentzer and Kahn (1995) review all articles published in the Journal of Business Logistics between 1978 and 1993.

[129] cf. Mentzer and Kahn (1995), p. 232

[130] cf. Stock (1997), pp. 521

[131] cf. Soni and Kodali (2011), p. 258-259. Soni und Kodali (2011) review 569 papers published from 1994 to 2008 in 21 selected academic journals.

transition of electricity generation. Both presented enabling Auto-ID technologies, bar code and RFID technology, might assist.

Radio frequency identification has become a 'hot' and innovative topic in fields of supply chain management, manufacturing and logistics.[132] As the basis of the upcoming comparative research design of this thesis, the two relevant innovative enabling technologies are presented in the following.

2.2. Comparative research for enabling technologies within supply chain innovation

The elements of today's supply chain management – as stated in figure 1 and in appendix 4 – include the active management of processes, organizational structures as well as enabling technologies for actively manage the financial, information and material flow. An efficient and effective management of supply chains requires detailed and real-time information about the products and its actual location.

McFarlane et al. (2003) defines Auto-ID technology as the automated extraction of the identity of an object.[133]

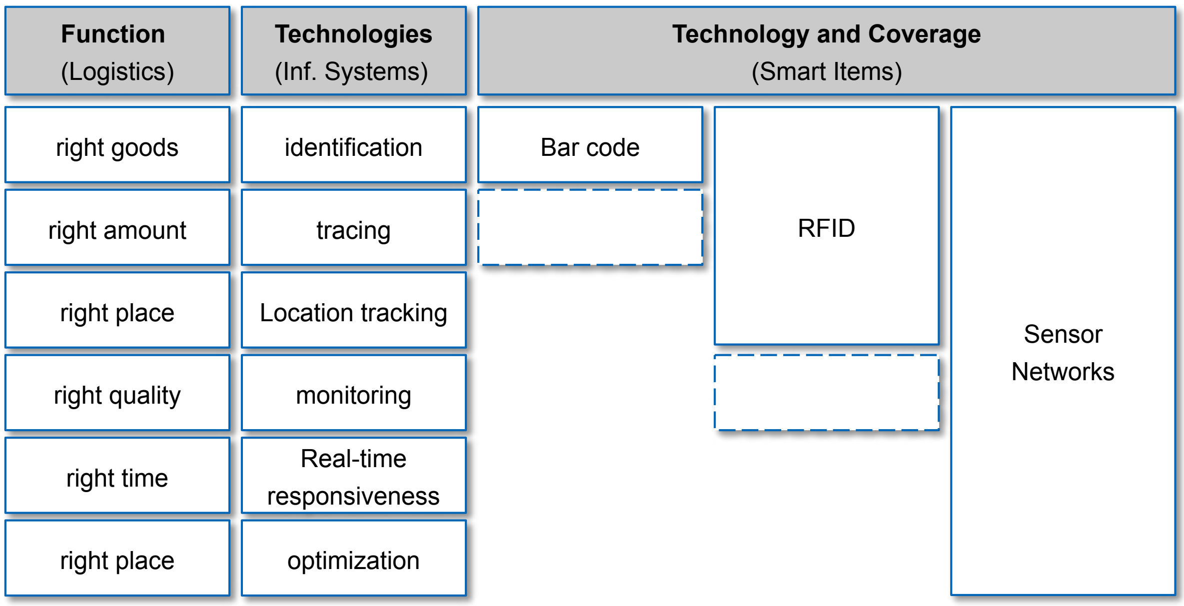
The importance of information technology in an integrated supply chain management environment has risen since the 1980s. Prior to this time, a significant portion of the information flow between functional areas within an organization, and in an integrated supply chain with its different supply chain organizations, was paper-based. These paper-based transactions and communications were slow, unreliable and error proven and therefore decreasing the company's efficiency in being able to design, develop, procure, manufacture and distribute its products. On theses grounds, the paper tagging systems have begun being replaced by a broad class of technologies called Automatic Identification and Data Capture, ADIC. The procedure of automatic data capture in logistics covers the identification of items, the automatic capture of relevant data and the communication with a database.

In literature and today's business operations, Automatic Identification and Data Capture are referenced by the term 'Auto-ID'. As shown in appendix 6, the numerous Auto-ID technologies can be clustered in the following main Auto-ID procedures: Optical character recognition systems, biometric procedures, smart cards and the most relevant Auto-ID procedures for supply chain management, bar code and Radio Frequency Identification (RFID). [134]

[132] cf. Ngai et al. (2008), p. 510
[133] cf. McFralane et al. (2003), p. 365
[134] cf. Banks et al. (2007), pp. 3

As described above, the basic logistic functions are to transport the right goods in the right quantity and right quality at the right time to the right location.

Information technology can create smart items to perform these functions in an efficient and effective way, as described in figure 4. The three most relevant concepts of Auto-ID technology can be attributed according their technological capability (from basic to advanced) to each logistic function.



Source: derived by author from Decker et al. (2008), p. 158

Figure 4. **Role of Auto-ID technologies in logistic processes**

Bar code technology including their described advantages can be stated as the current state of the art technology for electronic identification. The line-of-sight requirement limits the detection of single items within in a pallet and the technique of tracing meaning the detection when an item gets lost. RFID technology and the upcoming technology of sensor networks in the sense of cyber-physical systems facilitates advanced Smart Items in the theory of a Smart Factory.[135]

In the following chapters 2.2.1 and 2.2.2., both technologies will be portrayed. Two-dimensional bar code technology is presented first highlighting the reasons for success as well as the limitations of bar code technology in supply chain management.

[135] cf. Decker et al. (2008), p. 158-159

2.2.1. *Two-dimensional bar codes in supply chain integration*

The technology of the bar code revolutionized the supply chain management and logistics in general. The world-changing technology of a one-dimensional bar code was invented in the 1950s, when the commercial solution was registered as a U.S. patent to IBM researchers Bernard Silver and Norman Josef Woodland at October 7, 1952. In June 26, 1974, a bar code reader scanned the first bar code labelled product, a pack of Wrigley's chewing gum at Marsh's supermarket in Tory, Ohio.[136]

Bar code technology in today's supply chain management

The types of optical coding can be grouped into read-only or read-write and by three dimensions - one, two or three-dimensional bar codes.[137]

- One-dimensional bar code is a series of vertical alternating black and white stripes to contain the information. Classified as an optical electronic technology, the laser light is reflected by a bar code symbol and read by the scanner. The size and length of the bar code restricts the amount of information stored and the probability to read the information with out error. The ubiquitous International Article Numbering (IAN) is the most common format and is an international equivalent to the North American standard Universal Product Code (UPC). Today, more than 60 percent of all grocery stores in the US use bar coding technology.[138]
- Two-dimensional bar codes, also called 2D bar codes or bi-dimensional bar codes can encode numerical digits, alphabetical characters and symbols. Four main categories of 2D codes can be distinguished: Composite / Staple / Matrix Codes and Dotocodes.

  One relevant 2D bar code within supply chain management is the QR code, invited in 1994 by the Denso Ware Incorporation and developed for supply chain processes of the Toyota Inc., is one and the most popular of more than 30 types of Matrix Codes worldwide. Today, the use of QR codes is common in our daily lives, mostly in combination with cell phones accessing related downloads information on websites.

  Data Matrix code, as presented in appendix 7, is a 2D bar code with higher information destiny in relation to the size of the code and an increased potential for error correction and become extremely widespread in different industries.[139]
- Three-dimensional bar codes apply colour as the third dimension to store information and are so far of less relevance for supply chain management and integration.

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[136] cf. Banks et al. (2007), p. 30

[137] cf. Lenk (2002), p. 17. In this thesis, bar codes are considered as read only option. Read-write barcode on special interlayer are not in scope of supply chain management.

[138] cf. Banks et al. (2007), p. 32

[139] cf. Morrison (2010), p. 25-26, Lenk (2002), pp. 15, and Kato et al. (2010), p. 52

Two-dimensional bar codes are applied in a wide range of industries, for example the automobile industry for marking objects in logistic and production processes or the postal service industry. The type of bar code might differentiate according to the main focus of the industry, logistic or retail. An actual example in the pharmacy industry applies a data-matrix / two-dimensional bar code system in order of prevention of entry of falsified medical products for human use into the legal supply chain.[140]

Reasons for success of bar codes in supply chain management

The reasons for success of 2D bar codes in supply chain management can be stated as following:[141]

- Standardization of various types of 2D bar codes worldwide, see also ISO/IEC 16022, which allows implementation under stable conditions.
- Flexible filed of application due to manual or automatic code reading on short distance and high speed, for instance in many postal services while reading printed postage stamps.
- Speed and amount of data identification is high in automated facilities.
- Producibility is relatively simple due to today available print techniques and equipment. 2D bar codes can be printed with the same technical effort as 1D bar codes.
- Space requirement on products or packaging is small.
- Amount of data coded can be high with several thousand symbols compared to 20 characters carried by a traditional 1D bar code.
- Capability of integration in existing supply chain environments including hardware such as CCD scanners, printers and enterprise resource planning (ERP) systems.
- Data security according to code specification and resulting error correction capability. The algorithm Reed Solomon generates the total code information even if 25 percent of the code is destroyed.

Limitations of bar codes in supply chain management

The limitations of bar code technology are reasons for the recent hype of RFID technology:[142]

- Line-of-sight scanning is one of the major disadvantages of 2D bar codes. To scan properly, bar code needs to be applied to packaging or a location available for a direct line-of-sight connection to the scanner.[143] In case of large quantities of materials with a high (internal) turnover such as in retail industry, idealized RFID technology takes advantage.

[140] cf. Mortimer (2005), p. 15-16, Lenk (2002), p. 19, Formiga et al. (2011), p. 266, The European Parliament and of the Council (2011, assessed 28.12.2013), Franklin (2011), pp. 1602, and Röhrig-Friese (2012), p. 247

[141] cf. Lenk (2002), pp. 20, Morrison (2010). p. 25-26, Formiga et al. (2011), p. 266-267, and Brown (2007), p. 125-126

[142] cf. Banks (2007), pp. 30

[143] cf. Harish (2010), p. 35

- Read range, physically separate reading and environmental susceptibility limit scanning of bar codes. Harsh and dirty environments have to be considered in decision on bar code technology implementation.
- Access security due to the visibly on the outside of packaging and challenges of replications limit bar code technology compared to RFID technology.
- Amount of data stored and the lacking read-write capability might limit bar code technology in extended supply chains.

Banks et al. (2007) describe bar codes as a "globally proven technology that is easy to use, and [... is] fairly cheap compared to RFID tags and infrastructure to support an RFID-based solution"[144]. Today, it is still the most frequently used technology in tracking, even though the technically advancing RFID applications.[145] Further technological innovation allows electronic bar coding storing the identifier in the memory of a RFID tag to answer logistic question 'What, which, where?', while only sensors in combination with RFID or network technology have the potential to answer the 'How?' question.[146]

The author identifies bar code technology as still relevant for innovation in inter-organizational supply chain. Next to the stated limitations of this enabling technology, the author states the potential for successfully meet the present day goals of the future supply chain management. Next, RIFD technology in supply chain management will be presented.

2.2.2. Radio Frequency Identification technology in supply chain integration

In this part, relevant aspects of RIFD technology in today's supply chain management will be explained. Based on the current state of the art of business research regarding RFID technology in supply chain integration, the innovative potential as well as the benefits and costs within the concept of the Internet of Things are presented.

RFID technology in today's supply chain management

The term 'RFID' stands for Radio Frequency Identification, which is a wireless communication technology that enables users to uniquely identify tagged objects or people. Banks et al. (2007) explains the technology in its simplest form as the process and physical infrastructure by which a unique identifier, within a predefined protocol definition, is transferred from a device to a reader via radio frequency waves.[147]

A RFID system contents three basic components that are explained in relevance to this research and therefore exclusive of detailed analyses of underlying physical laws of

[144] Banks et al. (2007), p. 33-34
[145] cf. Hinkka and Tätilä (2013), p. 406
[146] cf. Kato et al. (2010), pp. 127
[147] cf. Banks et al. (2007), p. 3

electromagnetism and nuances encountered in dynamic radiofrequency environments. The three basic components are the tag, the reader and the controller:[148]

- Tag (also called transponder)

  The RFID tag varies in shape, size and capabilities. The tag needs to be selected or designed according to both business and technological requirements. The tag's essential components are an antenna, an integrated chip and a printed circuit board / substrate.

  Two major classifications of RFID tags according its power supply can be conducted: active, passive and semi-passive. In contrast to passive RFID tags, active tags contain an own power source, which allows them to be extremely flexible in terms of functionality they can offer. Active RFID tags allow a greater read range which might allow the tag to be read through materials that are usually impenetrable to magnetic radiation and further peripheral functions can be supported by active RFID tags such as temperature, humidity, and pressure sensors, as well as writable memory. Some handicaps of active RFID tags are the bigger size, higher cost compared to passive RFID tags and limited power source.

- Reader (also called Integrator or read/write device)

  The second of the three basic components of a RFID system is the RFID reader or also referred to as the integrator because they query tags as the tags enter its read range. The task of the reader is to arrange the communication with any tags in its read range and then presenting the tag's data to an application for further processing.

- Controller (also called a host or middleware)

  The third basic component of a RFID system is the controller / middleware. The middleware is a running database including control software, most often in form of a personal computer or a workstation.

Today's usage of RFID technology is an integrated part in our everyday life. The range of applications of the emerging RFID technology has spread far beyond the areas of supply chain management, manufacturing and logistics. The technology is used in applications such as preventing theft of automobiles and merchandise, collecting tools without stopping or manual interaction, managing traffic, automating parking, fabric and clothing library services, buildings management, animal detection, aviation, controlling access of persons and vehicles to gated communities, municipal solid waste management, museums and as pioneers animal detection and retailing.[149] The next steps of development for RFID technology will cover technological aspects, such as reduction in size of the circuit and antenna, an increased functionality and reliability while further reducing the cost of tags. In addition, the

[148] cf. Banks et al. (2007), pp. 61

[149] cf. Landt (2005), pp. 8, Banks et al. (2007), pp. 25, Ilie-Zudor et al. (2011), p. 229, Ilic et al. (2009), p. 13, Chao et al. (2007), pp. 270 and Thoroe (2009), p. 123

development of application software and of privacy policies compared with consideration of other legal aspects will be further evolutional milestones for RFID technology.[150]

In contrast to barcode, RFID technology enables the automatic identification of every single item and its virtual illustration. In the first step, the unique identification of at least a batch size might be sufficient for requirements of production or the supply chain management. The extended version of local RFID technology applications is the Internet of Things, in which computing becomes invisible into everyday life.[151] Weiser envisioned ubiquitous computing by stating:

"The most profound technologies are those that disappear. They weave themselves into the fabric of everyday life until they are indistinguishable from it."[152]

State of the art of business research of RFID technology in supply chain integration

In the past years, numerous publications regarding RFID technology in different business processes and industries have been designed due to the growing interest regarding this Auto-ID technology. These publications consist of a large number of white papers and technical reports regarding RFID technology mainly in supply chains and manufacturing processes.

Several academic researcher reviewed literature regarding state of the art on RFID technology in supply chain management. In the following, it will be concentrated on relevant literature with the focus on RFID technology and its impacts on a supply chain in general.[153]

Zhu et al. (2012) prepare the most actual literature review of RFID technology and its managerial applications in different industries by naming the functionality and potential impacts in supply chain management.[154]

Sarac et al. (2010) classify literature according two criteria: content orientated research covering the main problems of supply chain management and methodology orientated research including different approaches analysing the benefits of RFID technology. According to this research, publications of practical papers mostly use the approach of pilot projects, case studies and return on investment (ROI) analyses. Main topics are inventory management, logistic and transportation, assembly and manufacturing, asset tracking and object location and environment sensors. The most recently numerous published academic papers mainly use analytical or simulative approaches next to case studies, ROI analyses and literature reviews for researching potential benefits of RFID technology in supply chains. Authors of academic

[150] cf. Landt (2005), p. 11

[151] cf. Mathew et al. (2013), p. 1

[152] Weiser et al. (1991), p. 66. According to Becher (2011), the European version of ubiquitous computing is the concept of ambient intelligence. (cf. Becher (2011), p. 73)

[153] Most recently and not in the focus of this thesis, Yao et al. (2012) carried out a literature review of the adoption and implementation of RFID technologies in healthcare.

[154] cf. Zhu et al. (2012), pp. 153

papers are mostly interested in supply chain problems that RFID technology has the possibility to solve.[155]

Ngai et al. (2008) state in their academic literature research that up to more than one third of all RFID technology research in this 11-year time frame concentrates on technological aspects wherefrom 80 percent are related to RFID tags and antennae and that the majority of the reviewed literature, using the descriptors 'RFID' and 'radio frequency identification' in major electronic databases, has been published in technical journals even tough the trend to more publications in management and business journals is identified. In addition, research published in this time period shows the focus on specific events of the supply chain, mainly issues related to internal operations.[156]

Chao et al. (2007) analyse RFID technology innovations, adoptions by organizations, and the market diffusion. While lacking in a critical analyse on the listed papers, main findings of this research are the identification of the United States of America as the country with to most RFID related publications, an increasing number of papers published to end of the reviewed time frame, and an overview of RFID technology diffusion within selected industries.[157]

Delauny et al. (2007) research literature in the field of inventory management subject to inventory inaccuracies and the potential impact of a technological innovation such as RFID technology. Overall, four types of errors in retail stores and in the warehouse context are identified: shrinkage, misplacement, random yield from supplier and transaction type of error. Furthermore, future research directions are stated, such as inventory inaccuracies in reverse and inter-organizational logistics.[158]

Nemeth et al. (2006) focus on the review of publications to the state of the art of RFID technology systems. The paper covers mainly challenges and possibilities of its implementation within various supply chains at that time.[159]

Dolgui and Proth (2008) also review the literature with the focus on inventory management such as the bullwhip effect and methods to reduce its negative impacts along the supply chain. A special section deals with privacy concerns as one of the most important problems of RFID

[155] cf. Sarac et al. (2010), pp. 78. Sarac et al. (2010) compiled a literature review of 142 publications between 1958 and 2009 focusing on the impact of RFID technology on supply chain management.

[156] cf. Ngai et al. (2008), pp. 511 and Gunasekaran and Ngai (2005), p. 447-448. Ngai et al. (2008) present a literature review of 85 papers published between 1995 and 2005 in 56 academic journals categorizing four factors: technological issues, application areas, policy and security issues, and other issues.

[157] cf. Chao et al. (2007), pp. 268.Chao et al. (2007) searched the database of the Science Citation Index for RFID-related materials published from 1991 through November 2005 by categorizing e.g. publication country, institution, year, document type, and subject category. Ho (2009) published a comment regarding the literature review undertaken by Chao et al. (2007) noting some mistakes regarding the data and methods followed in the paper. However, this comments is not in contrast to the stated findings by Chao et al. (2007).

[158] cf. Delaunay et al. (2007), pp. 20

[159] cf. Nemeth et al. (2006), p. 243

technology in today's environment. Some techniques to protect privacy are proposed, such as tag killing, putting tags to sleep and blocking schemes.[160]

Innovative potential of RFID technology within supply chain integration

In literature, a lot of advantages of implementing RFID technology in supply chain management are described. The listed consolidated findings vary to several aspects, such as their relevance for supply chain management in general. Numerous research results are based within specialized supply chains, product categories and geographical areas- some are even limited to a local areas and even city limits or to an RFID technology implementation within an intra-organizational supply chain event.

Based on the literature, some of the main benefits of RFID technology in supply chain management are presented. It will be focused on challenges of supply chain management, regarding which RFID technology has the potential to improve: inventory inaccuracy, the bullwhip effect and replenishment policies.

- Inventory inaccuracy:

  Inventory inaccuracy in inventory management is a basic and important issue in almost every supply chain. As Kang and Gershwin (2005) state, many companies have automated their inventory management process and now rely on information systems when making critical decisions. If the information is inaccurate, the ability of the system to provide a high availability of products at the minimal operating cost can be compromised.[161]

  Sarac et al. (2010) present a survey on the different causes of inventory inaccuracy and classify them into four groups: transaction errors, shrinkage errors, inaccessible inventory and supply errors.[162]

  The first group of errors of inventory inaccuracy, the transaction errors, include scanning errors, incorrect identification of items, delivery errors and shipment errors, which occur when a customer receive wrong items and might be able demanding a refund or the supplier has to pay double transportation cost.[163] Scanning errors and comparably the incorrect identification of items generally occur when logistic processes deal with two similar items.[164] Delivery errors include differences between the delivery and the required quantity at customer's point and the delivery of wrong products to the wrong direction.[165]

[160] cf. Dolgui and Proth (2010), pp 109 and p. 189-190
[161] cf. Kang and Gershwin (2005), p. 843, Hardgrave and Miller (2008), p. 114 and Thiesse and Condea (2009), p. 33
[162] cf. Sarac et al. (2010), p. 80-81 and Rekik and Jemai (2009), p. 169
[163] cf. Raman (2000), p. 106 and Sarac et al. (2010), p. 80
[164] cf. Agarwal (2001), p. 18
[165] cf. Lee and Özer (2007), p. 48

The second group of errors of inventory inaccuracy, the shrinkage errors and also called stock loss, include all types of errors that cause loss of products ready for sale or production. Reasons are employee theft, shoplifting, administration and paperwork error and vendor fraud.

The third group of errors of inventory inaccuracy, the inaccessible inventory and also called misplaced items, can be explained as products, which are not in the correct place and therefore not available for internal usage or external sale.[166]

The fourth group of errors of inventory inaccuracy, the supply error, is covered limited in literature. According to Rekik (2011), product quality, yield efficiency and supply processes can affect inventory inaccuracy. The physical inventory is not known and one consequence might be a difference between the physical inventory and the inventory in the information system most probably if the product quality is low or a production process has low yield or a supply process is unreliable.[167]

According to literature, RFID technology has the potential to limit or even solve the problem of inventory inaccuracy, for example by improving the traceability of products and the visibility within the supply chain.

- Bullwhip effect:

  Another potential benefit of RFID technology in supply chain management arises from the important phenomena called the bullwhip effect, which has been studied for about fifty years. The bullwhip effect was first introduced by Forrester (1958) and can be explained as demand variations of the customer becoming increasingly large when they diffuse backwards through the supply chain.[168] Forrester (1958) observes a fluctuation and amplification of demand from the downstream to the upstream of the supply chain by stating an increasing variance of customer demand at each step backward in the supply chain - from the customer to the retailer, to the distributor, to the producer and each supplier of raw materials. A main cause of this amplification is the difficulty in information sharing between each actor of the supply chain.[169]

  The bullwhip phenomenon has been recognized in many diverse markets. Its sources and factors of controlling are researched by several researchers. The key drivers of the bullwhip phenomenon are the lack of information sharing, communicating and collaboration between the supply chain partners. This causes information distortion as

[166] cf. Sarac et al. (2010), p. 80
[167] cf. Rekik(2011), p. 173 and Sarac et al. (2010), p. 80
[168] cf. Stevenson (2011), p. 681
[169] cf. Forrester (1958), pp. 43, Sarac (2010), p. 82, and Dolgui and Proth (2010), p. 115

well as delays in information and material flows and dare the bullwhip effect in the upstream supply chain.[170]

Lee et al. (1997) analyse the main causes of the bullwhip effect or whiplash effect. Four main causes have been identified: demand signalling, order batching, fluctuation process and shortage game.

Demand signal processing describes the effect of distortion of demand information when the retailer issues order based on her updated demand forecast. As a consequence, the manufacturer loses sight of the true demand in market place and the production schedule on the distorted signals is inevitably inefficient. Batching of orders is a consequence of the periodic review process and processing cost of purchase transaction. Price variations are influenced by frequency and depth of the manufacture's trade promotion that cause asynchronized delivery and purchase processes. The shortage or rationing game is a result of the strategic decision by the retailer who accesses the possibility of being placed on allocation by the manufacturer. Such gaming behaviour might also arise due to the retailers' self-protection against imaginary shortage causing an information with little or even negative value to the upstream supply chain partners.[171]

Lee et al. (2004) arrange their research of the bullwhip effect from 1997 in order to technological innovations in the meantime. Next to the technological innovation of the Internet, the RFID technology and its potential value in order to real-time, accurate and extensive information sharing is identified to further reduce the bullwhip effect and therefore improve the supply chain performance.[172] Several authors infer from an adoption of Auto-ID technology such as RFID technology that the described bullwhip effect is reduced and the overall supply chain performance is improved. RFID technology considers the supply chain as a whole. Its ability of data capturing and real-time communication allow a drastically reduction of information distortion.[173] Bottani and Rizzi (2008) assess the economical impact of RFID technology and an automated information system using EPC on the fast-moving consumer goods supply chain. It is indicated that due an improved inventory visibility for the supply chain members the safety stocks and the bullwhip effect is reduced.[174]

- Replenishment policies:

  Replenishment policies are especially in retail industry a major aspect in supply chain management. Replenishment policies are methods for determining the frequency and the

[170] cf. Yücesan (2007), p. 134
[171] cf. Lee et al. (1997), pp. 555
[172] cf. Lee et al. (2004), p. 1891-1892 and DeHoratius and Raman (2008), p. 638
[173] cf. Sarac (2010), p. 82-83
[174] cf. Bottani and Rizzi (2008), p. 562

size of orders to maximise the customer satisfaction or to secure internal production capacity. Continuous or periodic review systems should lower ordering, holding and stock-out costs.[175]

The previous aspects also influence the replenishment process and can deeply affect the company's performance. Inventory replenishment decisions are made based on inventory data in the company's information system. RFID technology has the potential to ensure real-time and accurate inventory information. At the time when inventory inaccuracy occurs and no corrective action is taken, even a small rate of stock loss can disrupt the replenishment process and create severe out-of-stock situations. The lost sales due to stock loss can be substantially higher than the stock loss itself. In addition, Kang and Gershwin (2005) also show that the harmful effect of stock loss is greater in lean environments characterized by short lead times and small order quantities.[176]

Benefits and costs of RFID technology within the Internet of Things concept

The evaluation of benefits and cost within the decision-making process according to utility theory can be conducted according the following three components: information flow integration, physical flow integration and financial flow integration.

Angeles (2009) highlights the need of integration of all three components to achieve a full supply chain integration.[177]

Davenport (1993) suggests making a distinction in the role of information technology (IT) in business applications - IT as an enabler and IT as an implementer.

IT is often used as enabler in already existing or without detailed IT-consideration about designed business processes. However, IT has also the capability to function as an enabler in order to allow designing of new business processes which became potential by implementation of the new technology.[178] The Internet of Things might use existing Auto-ID technology to identify item - whether smart items by using barcode or totally automatic with RFID technology. In contrast, an error free RFID system will be one IT implementer to future cyber-physical systems in manufacturing.

Within supply chain innovation, the role of information technology is distinguished between an enabler or implementer role which influences the type of benefit, a company can expect from it. Direct benefits are rather caused as implementer whereas an enabler role leads to

[175] cf. Sarac (2010), p. 83
[176] cf. Kang and Gerswhin (2005), p. 855 and Hardgrave (2006), p. 52
[177] cf. Angeles (2009), p. 221-222
[178] cf. Davenport (1993), pp. 49 and Clark and Hammond (1997), p. 256

indirect benefits at the process level.[179] Leung et al. (2007) identify "cost-benefit analysis as a key component of deciding whether or when to deploy RFID technology in an enterprise."[180]

Cost factors of RFID technology, which are still larger than other current Auto-ID technologies, are still the major challenge of RFID systems to become a widespread application in supply chain management and its integration.[181] The obviously and hidden, the direct and indirect cost of a RFID implementation can be divided into six categories according to Banks et al. (2007) and are presented also in form of a cost tree in appendix 8.[182]

Benefits of RFID technology are structured in different ways, such as the following four different approaches:[183]

- Collecting and Grouping of benefits:
  Leung et al. (2007) develop a hierarchically at the profit and loss statement of business enterprises orientated RFID technology business value model as stated in appendix 9 to investigate whether RFID technology should be applied in a particular business case. In assessing the business value of an innovation, the value of an embedded growth opportunity needs also to be considered. Such a follow-on benefit of RFID technology is the related application in form of the Internet of Things.[184]
- Layer of impact:
  In relation to the layer of impact of benefits of RFID technology, the creation of business value by information technology can also be measured along three dimensions and effects, namely automational cover increased process efficiency, informational cover the improved handling of information, and transformational effect cover innovation and redesign of process and organizational structures.[185]
- Locus of impact:
  One or a group of stakeholder unequally benefit of the implementation of innovations in inter-organizational supply chain integration, as illustrated in appendix 10.[186]

In addition, literature also represents approaches of measuring the benefits and costs of RIFD-technology in indicator or comparison systems.

[179] cf. Leung et al. (2007), p. 52-53 and Weber and Kantamneni (2002), p. 312
[180] Leung et al. (2007), p. 53
[181] cf. Zipkin (2007), p. 70
[182] cf. Banks et al. (2007), pp. 175
[183] cf. Baars et al. (2009), p. 581, Davenport (1993), pp. 50, Mooney et al. (1996), p. 76-77, Scott Morton (1991), p. 16-17, Uckelmann (2012), p. 81, and Uckelmann and Scholz-Reiter (2011b), pp. 238
[184] cf. Leung et al. (2007), p. 53-54, Gille (2010), pp. 41, Sarac et al. (2010), p. 91, and Dimakopoulou et al. (2010), p. 428
[185] cf. Sobottka et al. (2012), pp. 72, Dedrick (2003), p. 22-23, Mooney et al. (1996), p. 76-77, Scott Morton (1991), p. 16-17, Tellkamp (2006), pp. 83, Zelbst et al. (2012), p. 332, and Baars et al. (2009), p. 584
[186] cf. Uckelmann (2012), pp. 83. Notice, service and infrastructure providers benefit only indirect and are therefore not included - see also Uckelmann and Schulz-Reiter (2011b), pp. 239.

The author clearly outlines, in summary of this sub-chapter, the innovative potential of this enabling technology for innovation in inter-organizational supply chains based on the current state of the art of business research as well as benefit and cost models. The author identifies challenges of today's supply chain management, RFID technology has the potential to improve, such as inventory inaccuracy, the bullwhip effect and replenishment policies, indicating the potential for meeting requirements of concepts for future inter-organisational supply chain management.

In the next chapter 2.3., the necessity for supply chain innovation in German electricity generation industry is derived.

2.3. Necessity for supply chain innovation in German electricity generation industry

The supply of electric power is one backbone of modern economies.

Three product specifications of electricity shape four steps of the value-added chain and the market design. The German market structure and its actors are in the middle of an adoption process under the new macroeconomic circumstances of the transition of electricity power supply including the phase-out of nuclear-fuel energy and intensive usage of renewables – the so-called German 'Energiewende'.

Based on the following characteristics, the need for supply chain innovation as well as the basic population of the qualitative and quantitative research design will be stated.

2.3.1. Value added chain and market structure in the electricity sector

The value-added chain and the market structure for electricity as a (trading) product are characterized by mainly three product specifications: Electricity is a homogeneous commodity. Electricity is not storable. Electricity has specific characteristics regarding price elasticity.[187]

The value-added chain of the electricity industry consists out of four major steps: generation, transmission, distribution and supply/trading. In addition, further services can be added such as a supporting value-added function, e.g. energy-related advisory services as a result of increased electricity prices and public initiatives regarding saving of energy.[188]

The market structure in the energy, especially electricity, sector is changing under various governmental restrictions resulting from the objective of the energy transition – the German

[187] cf. Ernst (2012), pp. 99 and Presser (2011), p. 28.29. Electricity is not storable in economic conditions, this means its storage capacity in accumulators does not fit to the market demand, and its storage in pump storage power plants include a net energy loss up to 30 per cent (see also Ernst (2012), p. 101).

[188] cf. Röösli and Seeholzer (1997), p. 141, Hennigs (2011), pp. 12, Ernst (2012), p. 97, and Sander (2011), p. 46

‘Energiewende’. In general, the German electricity market can be defined as national delimited with inclusion of relevant control areas in Austria.[189]

Market actors can be divided by the size of the company. Large and largest affiliated companies are acting as a vertical integrated company covering all steps of the value-added chain including electricity generation from all major energy carriers. Medium and small sized companies mostly focus on electricity distribution to final customers.[190]

Market participants in the electricity market can be categorized as following:[191]

- Interconnected companies combine activities along the entire value-added chain covering the electricity production, trading, transmission system operation and local distribution operation.
- Regional utilities act as a link between interconnected companies and smaller and public utilities. Regional utilities generate to limited extent electricity and focus on the transmission and distribution within its region.
- Smaller or rather public utilities profit from their local customer focus in distribution of electricity. Given that some public utilities operate own power plants, they can be separated in two types: Type A of public utilities generate a part of their demand for electricity in own small, medium or lager power plants, mostly in combined heat power plants for the simultaneous generation of electrical energy and heat for air conditioning/heating. Type B of public utilities act as pure trading companies by acquiring electricity from regional utilities, interconnected companies or the European Electricity Exchange (EEX).
- In addition and as a result of the energy revolution, the author of this thesis adds a further segment of market participants in the electivity market, namely de-centralised electricity producers. Individual market participants such as house owners, farmers or small citizens' associations operate photovoltaic systems, windmills as well as biomass power generation units with a small individual size. As stated in figure 5, these small and very small power units generate 24 per cent of the gross electricity generation in Germany in 2013, although sun and wind are not capable for base load electricity generation.

The basic population, as defined later in this chapter, is based on the stated market structure and market actors. The selection of participants of the quantitative research is also affected by the specific market design in the electricity market.

The research design of this thesis is also influenced by the risk of price manipulation in the electricity market and its existing market structure. By changing the generation capacity,

[189] cf. Monopolies Commission (2014), p. 59 and Monopolies Commission (2009), p. 59-60
[190] cf. Hennings (2011), p. 125
[191] cf. Röösli and Seeholzer (1997), p. 141-142 and Hennigs (2011), p. 125-126

the price for electricity is also changing based on the principles of supply and demand that are relevant for the market of electricity. The amount of electricity supplied is price-inelastic and comparatively difficult to influence. The amount of electricity generated is prone to be influenced if market participants control relevant generation capacity.[192]

In contrast to French electricity industry, the market structure in Germany is heterogeneous. The French Électricité de France (EDF) has a such a high market share in France that a competitive market environment even with latest structural improvement in France could not be reached so far. EDF is the biggest player in the European Central West Region with a 2.5-fold capacity compared to the German E.ON and RWE.[193] The four big players in the German electricity market are RWE, E.ON, EnBW and Vattenfall Europe. In 2005, the Monopolies Commission stated a collective dominant market position of RWE and E.ON.[194] The market share of the four interconnected companies for not by the EEG law compensable capacity drop from over 80 per cent in 2008 to 73 per cent in 2012.[195] In 2014, the Monopolies Commission state that competitive situation in the market for conventionally generated electricity has significantly improved compared to previous investigations due to less potential of exercising market power by the dominant four big market participants.[196]

The author applies the stated value added chain and market structure in the electricity sector in the thesis' research design. On the basis of the stated competitive market situation, the qualitative research in this thesis needs to be adjusted due to legal purposes. The author analyses in the following the industry's market design and derives the need of supply chain innovation for the upcoming transition of current supply chain management processes to future processes in order to meet the predatory market competition.

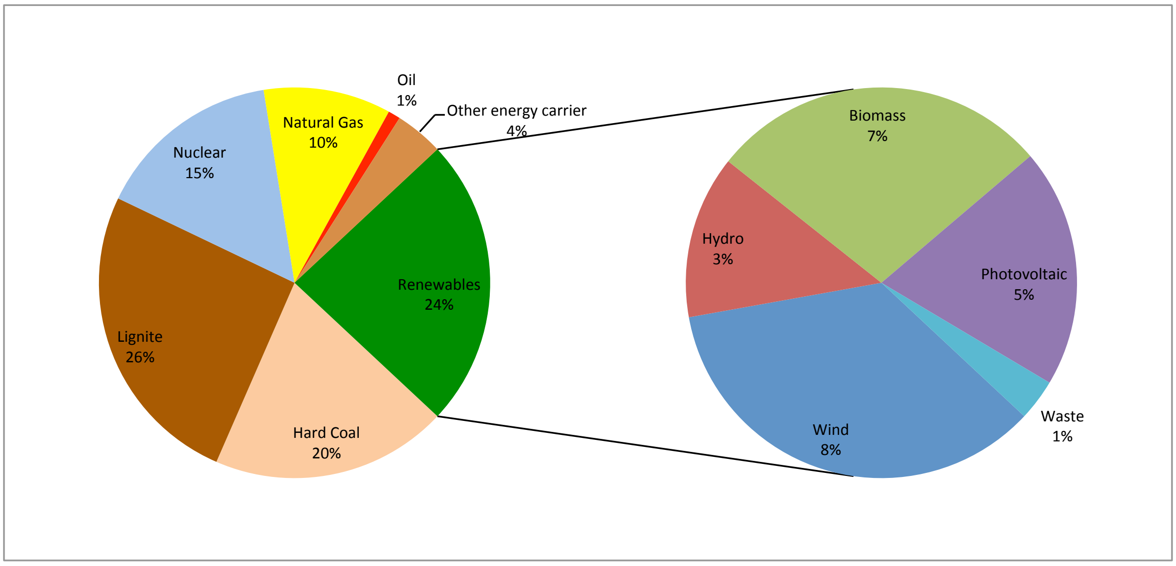
2.3.2. Market design determines specific supply chain management requirements

The current mix of energy sources for electricity power supply in Germany displays a development stage in the middle of the so-called German 'Energiewende' - the German transition of electricity power supply including the phase-out of nuclear-fuel energy and intensive usage of renewables. The first type of fuel for the energy supply in households is wood until the fist half of the 18th century and the invention and technical mature of wind and hydrodynamic power. Had coal represents the basis for the economical development in the 19th century and totals to a portion of 90 percent of commercial electric power supply around 1900. At the end of the 19th century, the mineral oil begins its success as an energy source for

[192] cf. Kaminski (2012), pp. 5 and Ernst (2012), pp. 110
[193] cf. Schwarz et al. (2007, accessed 02.05.2014), p. 19 and Ernst (2012), p. 108
[194] cf. Monopolies Commission (2009), p. 15, Ernst (2012), p. 116, and Hennigs (2011), p. 127
[195] cf. German Federal Network Agency for Electricity, Gas ... (2013), p. 31
[196] cf. Monopolies Commission (2014), p. 88

automobiles as well as the energy sector afterwards. Natural gas is deployed as an energy source in the United States of America before the First World War and in Europe after the Second World War. The commercial utilization of nuclear power begins in industrialized nations in the 1960s.[197]

In 2013, as stated in figure 5, the renewables are a major energy carrier for the gross electricity generation in Germany in 2013. Next to the fossil and nuclear energy carriers, renewable energy carriers, resulting from wind, biomass and photovoltaic technology, generate 24 percent of the gross electricity generation. The increase of the renewable energy carriers is based on the rapid increase of wind (from 9,5 in 2000 to 53,4 bn kWh in 2013) and photovoltaic power generation (from 0,1 in 2000 to 30,0 bn kWh in 2013).[198]



Source: derived by author from Working Group on Energy Balances /'Arbeitsgemeinschaft Energiebilanzen AGEB' (2014)

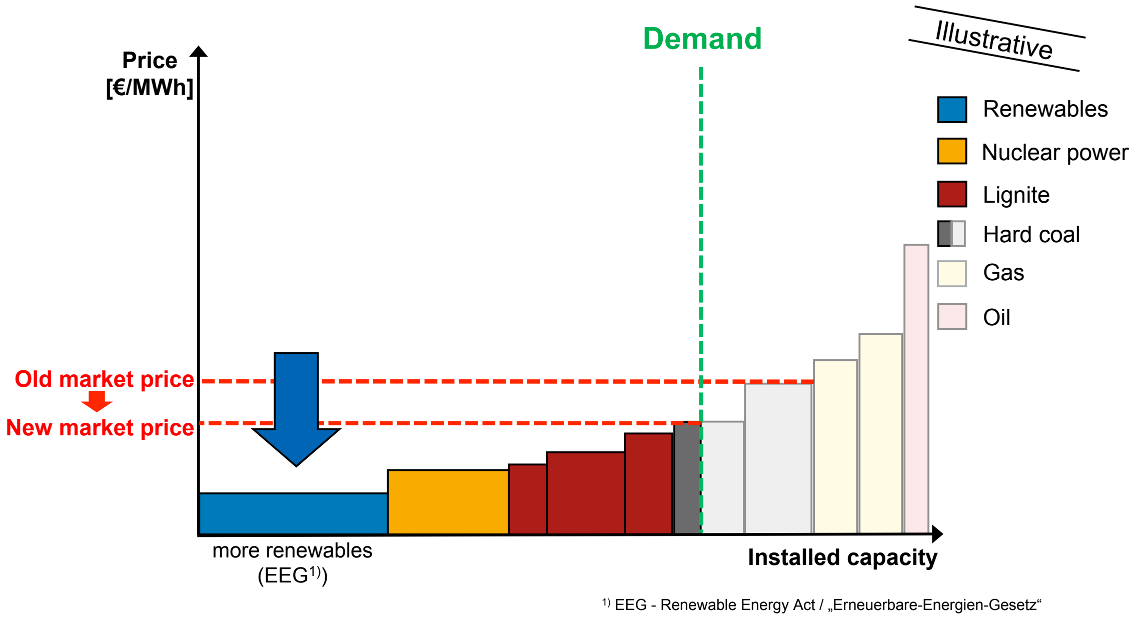
Figure 5. **Gross electricity generation in Germany by energy carrier (year 2013)**

The author identifies for today's market for energy and in particular for electricity in Germany far-reaching and ongoing changes based on the stated shift of energy carriers for the German electricity generation. Major influencing factors are Global and European agreements from Kyoto and Brussels concerning carbon dioxide emissions reduction next to the first European Liberalization Directive (96/92/EC) as well as German initiatives such as unbundling of vertical integrated market competitors and the German Renewable Energy Law (EEG). The newly established regulator German Federal Network Agency for Electricity,

[197] cf. Popp (2013), pp. 283 and Ströbele et al. (2012), p. 8-9
[198] cf. Working Group on Energy Balances… (accessed 16.05.2014)

Gas, Telecommunications, Post and Railway ('Bundesnetzagentur') in 2006 and the European Energy Exchange (EEX) influence the actual market design.[199]

Due to the stated product characteristics of electricity, the market of electricity requires to be composed of an equivalent of electricity demand and electricity generation. Given that electricity is not storable, the amount of generated electricity has to fit - aside from minimal system based variations – to the amount of supplied electricity at any time. This regulation is possible by adjusting the generation capacity simply by connecting or disconnecting power plants. The so-called merit order, as shown in figure 6, indicates the actual price for electricity and the ranking of available sources of electricity generation capacities in the spot market in ascending order of their short-run marginal costs of production.[200]



Source: compiled by author

Figure 6. **Merit-order effect of renewables in the German electricity market (in 2015)**

The author applies the stated merit order for indication of the importance for managing the short-run marginal costs of each power plant. Under the stated changing market conditions, especially the support of renewables by the Renewable Energy Act and its top-priority of renewable energy sources for the power grid input squeeze fossil power-generating units out of the market. Further potential market designs, such as a capacity market[201] design

[199] cf. Crastan (2012), pp. 50, Sander (2011), pp. 13, Hirschhausen (2009), p. 24-25, James and Fusaro (2006), pp. 19, European Energy Exchange EEX (accessed 19.01.2014), and OECD (2012), pp. 12

[200] cf. Ernst (2012), pp. 110

[201] A capacity market design in the electricity power generation industry should ensure security of electricity supply by providing a payment for reliable sources of capacity, alongside their electricity revenues, to ensure they deliver energy when needed.

as applied in the United Kingdom of Great Britain and Northern Ireland, requires also a strike cost management in preparation for the auctioning process of electricity supply capacity.

Within the merit-order market design, variable cost of the power-generating units are relevant – mainly cost of fuel and cost of emission certificates – in contrast to fixed cost – such as cost of operation, cost of capital and accrued liability. Only the cost of operation is capable of being influenced in the mid-term by the utility company.

Therefore the cost of operation is critical to successfully operate a power-generating unit. The implementation of innovations and potential underlying enabling technologies in the supply chain might increase supply chain performance and therefore decrease cost of maintenance and consequently cost of operation of the power-generating unit.

Dunker et al. (2012) highlight the importance and challenges of asset management and its five different strategies during the complete life cycle of the production facilities.[202] Due to the market design, the changing market environment and the maintenance strategy, the supply chain management has to meet specific demands in the electricity industry. The actual and to the market environment adapted maintenance strategy is a combination of a corrective maintenance and extended time based maintenance. Corrective maintenance is carried out in a short downtime – one or a couple of days - of the generation unit, whereas extended time based maintenance is carried out in form of an inspection, covering also technical developments such as or improving the flexible control and efficiency rates to adapt to changing market design. These inspections are last a couple of weeks in a yearly or more yearly time frames.

In both maintenance strategies, the downtime of the generation has to be minimized with the objective to maximize the availability for electricity generation of the unit. An existing power plant is mostly maintained and repaired on short notice. Supply chain management supported by innovative and enabling technologies such as Auto-ID technology might assist to minimize the risk of stock-out of requested materials and the related opportunity costs of a loss electricity generation.

The author of this thesis identifies, in summary of the previously stated findings regarding the comparative research for the two in this thesis relevant enabling technologies within supply chain innovation in combination with the stated market environment including its expected changes, supply chain innovation as necessary for the upcoming transition process of the current supply chain management process to a future process in order to meet the upcoming predatory market competition. In appendix 11, the author describes a schematic

[202] cf. Dunker et al. (2012), p. 16-17. Dunker et al. (2012) define five asset management strategies: corrective maintenance, extended time based maintenance, time based maintenance, asset refurbishment, and equipment replacement (Dunker et al. (2012), p. 22-23).

RFID technology reengineered receiving process in a current 'as is and non-integrated' and a potential 'to be and integrated' in the underlying supply chain. Currently and as stated before, most supply chain transactions in the German electricity power generation industry are performed with media discontinuity. This means the physical flow of material is still performed paper-based in form of an attached delivery note. A potential 'to be and integrated' supply chain process cover the principles of the Internet of Things concept with an combination of a real object with its virtual presence, illustrated in appendix 11 by an integrated data warehouse and exchange of information. The physical movement of a material lot size tagged with for example RFID technology is combined real-time identification of the material's location and real-time updated material movement data. Such an illustrative integrated supply chain process offers potential for reducing the cost of operation of in inbound and receiving process for all supply chain partners.[203]

In the following, the research design - which deals with the science (and art) of planning procedures for conducting studies so as get the most valid findings - for the qualitative and quantitative research method is stated. For each research method the research design, the data collection process and the measurement scale is outlined.

2.4. Semi-structured interviews with experts as qualitative research method

The research design and the data collection and measurement approaches of the semi-structured of interviews with experts is outlined in the following.

2.4.1. Interview guide prepared for ideal interview partner

Semi-structured interviews with experts are used in this thesis to gather substantial and specific information about impact factors for supply chain innovation and underlying enabling technologies in supply chains. In addition, the execution of semi-structured interviews with experts ensures stuffiness to collect information regarding adjustments of stated hypotheses and the development of the survey.

The research method expert interview is one method of qualitative researching. In contrast to quantitative research that can be described as distinctive research, qualitative research tends to be concerned with words rather than numbers by featuring an inductive view of the relationship between theory and research, an epistemological position described as interpretivist and an ontological position described as constructionist.[204]

[203] cf. Bottani and Rizzi (2008), p. 550, Hinkka and Tättilä (2013), pp. 411, and Cooper et al. (1997), p. 10
[204] cf. Bryman and Bell (2011), p. 386

The term ‘interview’ is not quiet commonly defined in literature. The term ‘interview’ can be dated back to the 17th century, its use within the today's scientific approach to the beginning of the 20th century.[205] Literally considered, an interview is an inter view, an inter-change of views between two persons conversing about a theme of mutual interest.[206] The term ‘semi-structured interview’ typically refers to a context in the interviewer has a series of questions that are in general form of an interview schedule but is able to vary the sequence of the questions. The interviewer has also some latitude to ask further questions in response to what is seen as significance replies.[207] The author is aware of the, in the research literature stated, strength and weaknesses of interviews, which need to be considered during the further planning, execution and analysing of the interviews.

The interviewee for the semi-structured interviews in this thesis is considered to be expert regarding one perspective of an implementation of a supply chain innovation as well as underlying enabling technologies in supply chains. According to literature, an expert or the rather the ideal interviewee is a quasi-exchangeable knowledge carrier.[208] Brians et al. (2011) define “people are referred to as elite [or as expert] if they have knowledge that, for the purposes of a given research project, requires that they be given individualized treatment in an interview. Their elite [or expert] status depends not on their role in society but on their access to information that can help answer a given research question”.[209]

The selection of the interviewees is carried out along the parameters stated by Gläser and Laudel (2010), for example which interviewee has the relevant information available, whether the interviewee is willing to share information and who is available for an interview. Gordaen (1973) points out that due to a high workload of some potential interviewee, it is advisable to interview organizational member at lower level if they have also access to the relevant information.[210] In this thesis, interviewees are selected from different levels of management level (see appendix 11).

Kvale and Brinkmann (2009) suggest nine different types of questions - introductory, follow-up, probing, specifying, direct, indirect, structuring, interpreting questions as well as silence to signal that the interviewee has the opportunity to reflect and amplify an answer.[211]

The interview guide is developed to recent research literature (for example Gläser and Laudel, Bryman and Bell, Kvale and Brinkmann, Börtz and Döring) and applied interview guides in

[205] cf. Kvale and Brinkmann (2009), p. 7
[206] cf. Kvale and Brinkmann (2009), p. 2
[207] cf. Qu and Dumay (2011), p. 246 and Bryman and Bell (2011), p. 205
[208] cf. Richardson et al. (1965), pp. 296, Bortz and Döring (2006), p. 248, and Gläser and Laudel (2010), p. 117
[209] cf. Brians et al. (2011), p. 166
[210] cf. Gorden (1975), pp. 196, Gläser and Laudel (2010), p. 117, and Richardson et al. (1965), pp. 296
[211] cf. Kvale and Brinkmann (2009), p. 135-136 and Gläser and Laudel (2010), pp. 12

previous supply chain management research (for example Ellram in supply chain management, Gläser and Laudel in general). Literature examples are also adopted for the interview report and written communication with interviewees before and after interviewing.
The author develops an interview guide containing the actual research model as well as the questionnaire for the following surveys (see also appendix 14). Next, the author deduces four groups of interviewees for the execution of the semi-structured interviews.

2.4.2. Four groups of experts identified for interview execution

The chosen experts can be segregated into four groups. Experts from research institutions and public organizations have capable information regarding the potentials and limits of each Auto-ID technology as well as information of the current state of research. Experts like business and IT consultants as well as Auto-ID technology standardization organizations have a great experience in Auto-ID technology applications and its efforts of standardization in various business operations in different industries. Senior executives in different companies and industries contributed their experience and actual activity plans related to innovation and enabling Auto-ID technologies in the firm's supply chain covering also suppliers and customers. Through this, ‘best practice’ approaches can be identified as well. The impact from and for the actual business is very important within this thesis - scientific work starts with comprehension of the requirements of the practice. An overview of the interview partners within each group of experts - as presented in appendix 13 - will be explained in the following.

Experts from research institutions such as the FIR (Institute for Industrial Management) at the RWTH Aachen University contributed capable information of each Auto-ID technology from a research perspective. In addition, actual research projects, funded by the European Union and the German state North Rhine-Westphalia (Nordrhein-Westfalen), and the projects research questions and hypotheses are discussed and actual findings presented.
The European EPC Competence Centre GmbH (EECC), founded by GS1 Germany, Deutsche Post World Net, Karstadt Warenhaus GmbH and the METRO Group has the objective of establishing RFID technology and the Electronic Product Code (EPC) as an international, cross-sector standard within Europe. The company's research lab is one of the world-leading technology research lab focusing to implement the RFID technology in business application.
In the background of actual security discussion in society and politics, the FIR (Institute for Industrial Management) at the RWTH Aachen University highlighted the need to involve and to contact the ‘The North Rhine-Westphalia Commissioner for Data Protection and Freedom

of Information - LDI NRW (Landesbeauftragter für Datenschutz und Informationsfreiheit Nordrhein-Westfalen)' within Auto-ID technology research projects.

The German Federal Office of Information Security (Bundesamt für Sicherheit der Informationstechnik) as a national security agency has the goal of promoting IT security in Germany. The association EuroData Council represents Germany works on the standardization of bar code and RFID technology in supply chain and consults and represent the Federal Republic of Germany in organizations like the International Standardization Organization (ISO).

Consultants and Auto-ID/RFID technology promoting organizations included experts from tagnoloy and admoVa consulting, both have great experts in evaluation and implementation projects of supply chain innovations and underlying enabling technologies, and GS1, the international not-for-profit association dedicated to design and implement global standards and solutions to improve the efficiency and visibility of supply and demand chains globally and across sectors.

Senior executives from non-utility industrial companies covered knowledge transfer from within and outside utility industry regarding best practice and general experience with supply chain innovation projects within the inter-organizational supply chain. World-market leading companies such as ThyssenKrupp and Deutsche Post DHL as well ESE apply Auto-ID technology as a core competence in their business.

Senior executives from the German utility industry were interviewed last. The identified actual research approaches as well as projects, initiatives and best practice approaches regarding supply chain innovations in other industries are incorporated in the interviews with senior executives of the German utility industry as the basic population of the questionnaire interview in the next research step in this thesis.

The author is limited in the execution of the semi-structured interviews by the German cartel. In particular, the German energy anti-trust law and competition law state limitations regarding the information exchange between companies on the same stage of competition in the German energy market.[212] By developing an adjusted research design covering different group of experts, the author ensures the interexchange of knowledge and experience regarding managerial impact factors of supply chain innovation and underlying enabling technologies.

In summary, the author conducts 13 semi-structured interviews with experts between November 2013 and November 2014. The positions of the interviewees, as stated in appendix 12, range from executive director, president of engineering, head of logistic or procurement departments to highly respected experts, relevant for this thesis.

[212] cf. Ministry of Economic Affairs, Energy… (accessed 21.03.2015)

2.4.3. Method of meaning condensation selected for measurement of results

The interviewee has been invited either by email or phone. The prepared interview guide is sent prior to the interview. Face-to-face-interviewing is the preferred approach for conducting the interviews. Due to travel distance or availability of interview appointment, some interviews are conducted in form of telephone interviewing.[213]

Upon approval of the interviewees, the interviews, as stated in appendix 12, are audio-taped by a mobile phone and sometimes additionally by a voice recorder. One interviewee explicitly refused to audio-tape the interview. One interview took place in a public environment and therefore the interviewer and interviewee waived to audio-tape the interview.

In addition, further interviews, which were not audio-taped and not listed in appendix 12, have been conducted and the findings from these are integrated in stating the research questions and hypotheses as well as validating the stated results and conclusion in thesis.

The results of the interview are contemporarily summarized. The minutes covering the main results is written at the day of the interview and reviewed on the following day(s). The minutes are sent to the interviewee within two or three days after the interview took place - latest at the following weekend after the interview took place.

Some interviewees also send additional comments, remarks and documentations in relation to the interview. This information is integrated into updated minutes.

The method of meaning condensation is applied for carving out the results of this qualitative research. Most scientific researchers look in the first step for method of measurement and then try to identify the meaning of the measurement. As Giorgi (1975) points out in his approach, the meaning is the measurement. According this approach as stated by Giorgi (1975) and Kvale and Brinkmann (2009), in this study the researcher gets directly to the meaning of the phenomenon by a method that systematically explores the meaning directly without going through the measurement process in the strict sense of the term.[214] The data expressed in terms of ordinary language is systematically analysed without necessarily transforming the data into quantitative expressions.[215] Results are stated in chapter 3.1.

2.5. Self-completion questionnaire survey as quantitative research method

To overcome the restrictions of qualitative research, the quantitative research method self-completion questionnaire survey is applied in this thesis.

[213] cf. Brace (2013), pp. 17. For a detailed examination of relevant data collection media see also Brace (2013).

[214] cf. Giorgi (1975), p. 101 and Kvale and Brinkmann (2009), p. 205-206

[215] Literature proposes also different ways of quantitative text analysis (see e.g. Gläser and Laudel (2010), pp. 197 and Brians et al. (2011), pp. 198).

In the next sub-chapters the design process including the deduction process of the questions from existing research literature and the pre-tests are stated.
In the following the data collection process presents the definition of the basic population.
Finally, the measurement scale including the questions is deducted from research literature.

2.5.1. Development of questionnaire analysed with structural equation modelling

The design of the self-completion questionnaire survey is stated in the following. The questionnaire is certified by the author according to the main steps - deduction of the questions from the literature, pre-test the survey with two experts, pre-test the survey with respondents similar to the basic population.

The survey is designed and administered according to the Dillman (2007) method for administering web-based surveys.[216]
The questionnaire contains 39 for the online and 41 questions for the fair trade survey to measure the impact of the stated managerial factor for innovation adoption in intra-organizational supply chain management on supply chain performance supplemented by to general questions characteristics of the respondent. The online questionnaire is stated in appendix 16, the questionnaire applied at the fair trade is stated in appendix 17.
A questionnaire is developed using existing questions from literature as far as applicable to measure the factors. Bryman and Bell (2011) recommend using questions that have been employed by other researchers for at least a part of the questionnaire.[217]
The questionnaire and the underlying measurement scale in this thesis are based on past research such as Chang et al. (2008), Patterson et al. (2003), Quetti et al. (2012), Zelbst et al. (2012), Green et al. (2009) and Cohen and Roussel (2005).[218]

A five-point Likert scale is used and arranged in a polarised way from ‘I do not agree’, ‘neutral’ and ‘I do agree’.[219] The author expects the respondent with a clear statement. The survey does not force the respondent to answer specific questions. All answer options are free to choose while only one answer option for each question is allowed. A free text field is only optional applied in question 39 for collecting the respondent’s email address.

The questionnaire is pre-tested. A pre-test or also called pilot test a draft form of the questionnaire is administered in a small sample from the sampling frame. Bryman and Bell (2011) advise that the pilot should not be carried out on people who might be members of the sample, which would be employed on the full study. They recommend finding a small set of

[216] cf. Dillmann (2007), pp. 372
[217] cf. Bryman and Bell (2011), p. 263
[218] cf. Chang et al. (2008), p. 207, Patterson et al. (2003), pp. 106, Quetti et al. (2012), pp. 318, Zelbst et al. (2012), pp. 329, Green et al. (2009), pp. 147, and Cohen and Roussel (2005), pp. 205
[219] cf. Friedrichs (1990), p. 175-176

respondents who are comparable to the members of the population from which the sample for full study will be taken.[220]

The questionnaire is verified with two experts – the supervisor of this thesis and one scientific coordinator of the doctoral program.

In addition, a pre-test is carried out with ten experts – seven students from the doctoral program and three managers of the utility industry at the different management levels according to the questionnaire. These students and managers are not part of the group of respondents in the following questionnaire survey.

The questionnaire is send to the to the respondents of the pilot-test, using the also the surveymonkey platform, and the respondent fill out the self-completion questionnaire. The respondent is interviewed regarding his thoughts and suggestions for improvement of the questionnaire.

As a result of this design process of the self-completion questionnaire survey, the instructions and the questions regarding their wording, phrasing, positioning as well as the sated ethical criteria of this thesis are adjusted prior to the full study. This design process should help to improve the respond rate by eliminating potential sources of difficulty, such as poorly worded questions.[221]

The self-completion questionnaire is analysed by a multivariate analyse technique. The structural equation modelling using partial least squares is performed in the software Smart PLS.

Structural equation modelling is a statistical technique for simultaneously testing and estimating causal relationships among multiple independent and dependent constructs. It consists of different sub-models.

The structural model, also called inner model, comprises the relationships between the theoretically derived latent variables: the independent (exogenous) variable adoption of innovation in inter-organizational supply chains including the five managerial impact factors as well as the dependent (endogenous) variable supply chain performance including effectiveness and efficiency.

The author derives a measurement model including both outer models within the structural equation model, which embodies the relationship between the empirically observable indicators of the latent variables.[222] The measurement model is stated in appendix 3.

[220] cf. Sharpe et al. (2011), p. 40, Brians et al. (2011), p. 169-170, and Bryman and Bell (2011), p. 262-263
[221] cf. Fink (2013), p. 7-8, Brace (2013), p. 191-192, and Dillman (2007), pp. 140
[222] cf. Backhaus et al. (2011), pp. 331, Urbach and Ahlemann (2010), p. 10, and Nitzl (2010), pp. 2

2.5.2. *Basic population derived from comparison of different sample frames*

The author collects the empirical data via a questionnaire survey after pre-testing in the time period from November 2014 to February 2015. As stated in chapter 2.3., the basic population of this research is the electricity generation industry in Germany. The companies within the German electricity power generation industry are invited to participate in the survey.

The population, defined as the universe of units from which the selection is to be selected, is the industry of power generation also called generation of electricity and electricity generation.

The sample, defined as the segment of the population that is selected for investigation, is selected based non-probability method approach.

The sample frame, defined as the list of all units in the population is from which the sample will be selected, is created by the author among the following databases available in December 2013 and January 2014.[223]

- Sample frame 1: German Federal Statistical Office / ‘Deutsches Statistisches Bundesamt’:
  The most valid and reliable database according to the stated quality criteria of this thesis and the defined industry is the database of the German Federal Statistical Office.
  Paragraph 15 in the German ‘Law regarding Statistics for Federal Purpose’ (Gesetz über die Statistik für Bundeszwecke / Bundesstatistikgesetz - BStatG) govern a obligation to give information to the Federal and State Statistical Offices. In paragraph 16 of the same law, nondisclosure of the received information is regulated.[224]
  The German Federal Statistical Office classifies business companies according to a nomenclature of economic activities - see also appendix 15.
  The chapter D and code 35 of the nomenclature of economic activities covers the energy supply, which can be divided by electricity power supply (35.1), gas supply (35.2) and combined heat and power generation (35.3).
  Electricity power supply (35.11) is divided into four main clusters - its generation (35.11), its transmission (35.12), its distribution (35.13) and its trading (35.14).
  Electricity power generation (35.11) is finally classified into electricity power generation without transmission (35.11.1), electricity power generation with supply by third parties for transmission (35.11.2) and electricity power generation without supply by third parties for transmission (35.11.3).[225]

[223] cf. Bryman and Bell (2011), p. 176
[224] cf. Bundesstatistikgesetz (1987), p. 7-8
[225] cf. German Federal Statistical Office (2008, accessed 18.01.2014), p. 102

The German Federal Statistical Office state 718 companies with more than 20 employees in the electricity power generation (35.11) segment in the year 2011, employing in total 193,923 people and achieve 403,675 million Euro sales.[226] On request by the author, the Research Data Centre of the German Federal Statistical Office state 267 companies in the electricity power generation without transmission (35.11.1).

- Sample frame 2: German Federal Network Agency – Bundesnetzagentur:

  The Federal Network Agency for Electricity, Gas, Telecommunications, Post and Railway, or Bundesnetzagentur as it is commonly known, has the goal to promote an effective competition in the regulated areas and ensures non-discriminatory access to networks.

  The Bundesnetzagentur lists existing power plants in Germany with a net nominal electricity capacity of at least 10 MW. It also includes capacities feeding into the German grid from Luxembourg, France, Switzerland and Austria. The Bundesnetzagentur's list shows also generation facilities of less than 10 MW, grouped by federal state and energy source. As of 16 October 2013, the Bundesnetzagentur lists a net nominal capacity totalling 183.4 GW (without final shutdowns).[227]

- Sample frame 3: Private credit agency:

  A list of all units in the population electricity power generation is also available by private credit agencies, also called a ratings service and in German called as 'Wirtschaftsauskunftei'. These companies are private owned with the purpose of giving advisory information regarding economical parameter of private persons and companies to business partners. Two main credit agencies are known to the author for accessing the sample frame for this thesis: Creditreform and Hoppenstaedt. For example, Creditreform is clustering the firm according to the German Federal Statistical Office as stated in sample frame 1. Creditreform list in the segment electricity power generation (35.11) 20,063 companies, in the segment electricity power generation without transmission (35.11.1) 2,242 companies.[228]

- Sample frame 4: German Association of Energy and Water Industries – BDEW:

  The German Association of Energy and Water Industries ('Bundesverband der Energie- und Wasserwirtschaft – BDEW') list 1,812 companies in the industry with largest investments in the German industry. The Association BDEW contains members of all

[226] cf. German Federal Statistical Office (accessed 19.01.2014). Number of Employees inclusive working owner. Sales exclusive sales tax, electricity tax and natural gas tax.
[227] cf. German Federal Network Agency for Electricity, Gas ... (accessed 12.09.2014)
[228] cf. Creditreform (accessed 19.01.2014) and Hoppenstedt (accessed 19.01.2014)

sizes and forms of organization with only a classification by the company's city and state.[229]

- Further sample frames:

  The author assesses further sample frames in order to define the list of all units in the population. The most relevant approaches will be introduced.

  The German Commercial Registry, in German ‘Handelsregister’, allows to search for companies in the shared register of company’s portal for the German federal states. However, any selection of industry segmentation is available. Only a search by name is possible.[230]

  Verivox and Check24 are referred as independent comparison portals for and energy and other services in Germany. The author of this state both customer platform as not completely independent and both do not necessarily contain all companies of the German utility industry, only these companies which want to be find and compared via this website by the customers. Verivox lists 1,096 companies for electricity, and Check24 lists 1,084 companies.[231]

  Further industry information is available by the European Energy Exchange (EEX), which operates a market platform for a broad range of energy and related products: power, natural gas, CO2 emission rights and coal. The EEX is referencing to the Federal Network Agency for Electricity, Gas, Telecommunications, Post and Railway (Bundesnetzagentur).

The population to the stated research question in this thesis can be best evaluated from units within the electricity power generation without transmission (35.11.1) segment, because in the segment's units / companies show a great potential and need for applying supply chain innovation and underlying enabling technologies in inter-organizational supply chains.

A comparison of the available databases, as shown in a schematic overview in figure 7, is grouped by number of companies, data quality and accessibility.

The best database for defining the sample frame and executing the self-completion questionnaire is the database from the German Federal Statistical Office, which is not accessible due to the stated legal restrictions.

The second best database is the list of power plants as stated by the German Federal Network Agency - Bundesnetzagentur. This database will be applied in this thesis.

The other databases by the private credit agency, The German Association of Energy and Water Industries - BDEW and the further organization such as Verivox and Check 24 provide companies in the electricity industry without matching the quality criteria oft his research.

[229] cf. German Association of Energy and Water Industries (accessed 19.01.2014)
[230] cf. German Commercial Registry (accessed 19.01.2014)
[231] cf. Verivox (accessed 19.01.2014) and Check24 (accessed 19.01.2014)

Sample	German Federal Statistical Office / 'Deutsches Statistisches Bundesamt'	German Federal Network Agency – Bundesnetzagentur	Private credit agency	German Association of Energy and Water Industries – BDEW	Further sample frames
Companies	718	≈ 700	≈ 2,000	1,812	≈ 1,000
Data quality	Best (official database, clear criteria)	Good (official database, clear criteria)	Business data, own criteria used	Data depends on membership	Market actors, various unclear criteria
Accessibility	Company names are not available	Names and further criteria available	Database is partly acquirable	Company names are available	Company names are available

Source: compiled by the author. Analysis is based on data available for the German electricity power generation industry (year 2014) from German Federal Network Agency for Electricity, Gas... (accessed 19.01.2014), German Federal Statistical Office (accessed 19.01.2014), Creditreform (accessed 19.01.2014), Hoppenstedt (accessed 19.01.2014), German Association of Energy and Water Industries (accessed 19.01.2014), German Commercial Registry (accessed 19.01.2014), Verivox (accessed 19.01.2014), and Check24 (accessed 19.01.2014)

Figure 7. **Overview of sample frames in German electricity generation industry (2014)**

The author pre-processes the list of power plants as stated by the German Federal Network Agency - Bundesnetzagentur – from September 12, 2014 according to the following criteria:

- Power plant status with status 'in operation':
  Survey participants of this thesis actually operate a power plant unit. Non-operating power plant units such as temporary or seasonal shut down or reserve power units do require less maintenance causing less supply chain activity.
- Net nominal capacity ('elektrische Netto-Nennleistung') - greater than 10 MW:
  Survey participants of this thesis operate a power plant unit with a net nominal capacity (effective electrical power) greater than 10 MW. Power units with less than 10 MW are less asset intensive power units, which require less complex operating, maintenance and supply chain management processes. New technologies in supply chain management are less adaptable for small and low asset valued company
- Power plant units without energy source of solar and wind power plants:
  Most solar and wind power plants are units of small and medium size und are regulated by the German Renewable Energy Law. Power units such as a single windmill or photovoltaic system are less relevant for implementing a costly new technology in supply chain management.

The author identifies for the execution of the self-completion questionnaire 276 companies with running electricity power installations and more than ten-megawatt electrical effective power, including e.g. fossil-thermal, nuclear, gas turbine and diesel fuel as well as relevant renewable resources.

The list of survey participants is stated in appendix 21. This classification comes close to the industry segmentation of electricity power generation without transmission (35.11.1) German Federal Statistical Office. The list of participants includes next to German companies also operators located in Luxembourg, Switzerland and Austria, feeding into the German grid.

Next to companies with a core competency in electricity power generation (35.11) such as the previously stated 'Big four' utility companies, large public utility companies, e.g. from Munich, Cologne, Leipzig and Frankfurt, as well as companies operating own power plants mainly for production purposes, e.g. Daimler, Volkswagen, Opel, BASF, Dow Chemical, Shell, TOTAL and ThyssenKrupp.

The author sends out the questionnaire in the time frame November 2014 to January 2015. The author uses the online platform surveymonkey for the execution of the online questionnaire. The author determines the names and contact details from respondents by an intensive online research. In addition, the author calls identified companies in order to find out the relevant respondent and/or to convince him or her to participate. The author requests in particular supply chain managers and professionals for participating in the survey.

Via the online platform surveymonkey, an initial mail, as stated in appendix 18, is attached to each invitation for participation at the questionnaire. The author sends out two reminder mails with appropriate time delay. The first reminder mail is states in appendix 19, the second one in appendix 20. In total, the author receives 27 respondents equalling 9,9 percent which is comparable to other research in industrial settings. The response rate does not differ between called and only emailed participants.

Due to a limited response rate and amount of responses, the author of this thesis collects additional responses from participants and visitors of the 13th International Trade Fair for Distribution, Materials Handling and Information Flow LogiMAT 2015 in Stuttgart, Germany in February 2015. This trade fair provides the trade audience with a comprehensive state of the art and outlook of all the main themes in the logistic sector.[232] Respondents of the online questionnaire are not invited a second time.

The stated research design corresponds with the "relational view" of inter-organizational completive advantage as stated by Dyer and Singh (1998), considering a dyadic/network unit of analysis in contrast to the resource-based view of individual firms within systems theory.[233]

In the following, the questionnaire and the measurement scale is affiliated.

[232] LogiMAT (accessed 31.01.2015)
[233] cf. Dyer and Singh (1998), p. 676 and Chen and Paulraj (2004), p. 121

2.5.3. *Measurement scale for each managerial impact factor and sub-factor*

The measurement scale is stated according the defined factors for innovation in inter-organizational supply chain management in chapter 1.4., referenced to actual research literature.

Organizational characteristics

The factor 'organizational characteristics' is divided into three variables as described in following table 1.

Table 1. **Measurement construct of factor 'organizational characteristics'**

Factor	Description	Question	References
Financial resources (+)	The availability of financial resources increases the rate of adoption.	The company allocates sufficient resources for the implementation of supply chain management (SCM) innovation. (Org1)	Kim and Garrison (2010), p. 395, Brown and Russell (2007), p. 254, Chwelos et al. (2001), pp. 317, Iacovou et al. (1995), pp. 471, Kauffman and Mohtadi (2004), p. 142, and Robey et al. (2008), p. 505
Top management (+)	Top management attitude and support facilitates the adoption and diffusion of new technologies.	The management sustainably supports the implementation of SCM innovation. (Org2) Adequate human resources are allocated by the management for the implementation of SCM innovation. (Org3)	Kim and Garrison (2010), p. 395, Cragg and King (1993), pp. 53, Brown and Russell (2007), p. 254, Premkumar and Roberts (1999), p. 472, Chwelos et al. (2001), pp. 317, Crum et al. (1996), p. 48, Iacovou et al. (1995), pp. 471, Karahanna et al. (1999), p. 188, Kauffman and Mohtadi (2004), p. 142, Teo et al. (2003), p. 40-41, Robey et al. (2008), p. 505, Sharma et al. (2007), p. 3758, and Premkumar and Ramamurthy (1995), p. 311
Company size (+)	Company size is measured by the number of employees and by the revenue in the last year.	Please indicate the number of employees within the company: (on the basis of the last business year not specified 0-99 100-199 200-499 500-990 1000-1999 2000 and more (Org4) Please indicate the company's revenue in the last year: (in Mio. Euro - on the basis of the last business year) 0-49 50-99 101-299 300-499 500-999 1000 and more not specified (Org5)	Measure No. of employees: German Federal Statistical Office / "Deutsches Statistisches Bundesamt", (2013, accessed 03.05.2014), Quetti et al. (2012), p. 321, Premkumar and Roberts (1999), p, 483, Chang et al. (2008), p. 207, Brown and Russell (2007), p. 254, Patterson et al. (2003), p. 98, Kimberly and Evanisko (1981), p. 699-700, Bruque (2007), p. 244, Kwon and Zmud (1987), p. 235, Wen et a. (2009), p. 25, Lee and Shim (2007), p. 719, and Premkumar and Ramamurthy (1995), p. 317 Measure Revenue: German Federal Statistical Office / "Deutsches Statistisches Bundesamt", (2013, accessed 03.05.2014), Angeles et al. (2001), p. 343, Patter-son et al. (2003), p.106, Kimberly and Evanisko (1981), p. 699-700, Bruque (2007), p. 244, Kwon and Zmud (1987), p. 235, Klein and Rai (2009), pp. 742, Lin and Ho (2009), p. 373, and Rai et al. (2006), p. 228

Source: compiled by the author

Financial resources support innovation in inter-organizational supply chains.

Previous researches clearly indicate the relationship of available financial resources and innovation adoption behaviour. The availability of financial resources increases the rate of adoption. The investment is often measured as perceived ROI. In this thesis and underlying research approach, the prediction of unequally distributed financial investments is not research in particular. Some authors access financial resources closely linked to organizational size in terms of revenue/sales and number of employees.[234]

Top management supports innovation in inter-organizational supply chains.

Kauffman and Mohtadi (2004) state that larger firms have more resources, including critical factors such as managerial skill for innovation adoption. This management potential might assist in performing large and complex innovation projects including significant cost uncertainty. Further organizational size and management related issues arise in the potential to create innovation networks and technological standards combined with the management's willingness to invest in innovation.

In contract to the increasing effect, the non-existence of these supporting factors limit innovation. Lack of (technological) knowledge, shortage in skills or managerial time discourages innovation.[235]

Company size equalling to organizational size supports innovation in inter-organizational supply chains.

In literature and previous studies, many researchers discuss the use of size as a surrogate for a formal structural factor of organizations on innovation. Whereas numerous researchers apply the number of employees as one sub-factor, Iacovou et al. (1995) deny a relationship between number of employees and innovation adoption behaviour. The number of the company's employees and the volume of sales are clustered on the base of the classification by the German Federal Statistical Office. The range is adapted due to changed focus of companies.[236]

The author applies in this thesis the construct of the company's number of employees and its revenue as measures of the company size. By asking for both criteria, the respondent needs answer to either one question and still allows an inference to the size of the organization. Since the respondent might perceive both questions as private or confidential, the answer option 'not specified' is given in the questionnaire.

[234] cf. Iacovou et al. (1995), pp. 471, Kauffman and Mohtadi (2004), p. 142, and Robey et al. (2008), p. 505

[235] cf. Cragg and King (1993), pp. 54 and Kauffman and Mohtadi (2004), p. 142

[236] cf. Kwon and Zmud (1987), p. 235, Patterson et al. (2003), p. 98-99, Iacovou et al. (1995), pp. 477, and German Federal Statistical Office (2013, accessed 19.01.2014), p. 11

Environmental characteristics

The factor 'environmental characteristics' is divided into four variables as described in table 2.

Table 2. **Measurement construct of factor 'environmental characteristics'**

Factor	Description	Question	References
Competitive pressure (+)	The competitive pressure in an industry increases the rate of adoption of innovations as countermeasures to face rivalry.	The competitive pressure in the utility industry increases the rate of adoption of innovations as countermeasures to face rivalry. (Env1)	Cragg (1993), p. 53, Kimberly and Evanisko (1981), p. 699, Bruque (2007), p. 244, Quetti et al. (2012), p.318, Chwelos et al. (2001), pp. 317, Fichman (2004), pp. 317, Iacovou et al. (1995), pp. 471, Lin and Ho (2009), p. 373, Sharma et al. (2007), p. 3758, Mooney et al. (1996), p. 75, and Premkumar and Ramamurthy (1995), p. 311-312
Innovation maturity (+)	The life-cycle phase of an (technological) innovation is crucial for its adoption and diffusion.	The life-cycle phase of an (technology) innovation is crucial for its adoption and diffusion. (Env2)	Rogers (1983), pp. 14, Fichman (2004), pp. 317, and Sharma et al. (2007), p. 3758
Industry environment (+)	The characteristics of the (supplier's) industry in which a SC operates influence the adoption of a technology.	The characteristics of the industry environment influence the adoption of a technology. (Env3)	Gatignon and Robertson (1989), p. 41, Chang et al. (2008), p. 204-205, Quetti (2012), p. 318, Morrel and Ezingeard (2002), p. 53-54, Brown and Russell (2007), p. 254-255, and Sharma et al. (2007), p. 3758
Uncertainty of environment (+)	Uncertainty exists due to imperfect information to organization's decision makers. Uncertainty drives the need for technological innovation.	The utility industry faces extreme change and uncertainty (energy transition / 'Energiewende') (Env4)	Wong et al. (2011), p. 198-199, Patterson et al. (2003), p. 102-103, Walton and Milton (1995), p. 121, Chang et al. (2008), pp. 205, Kwon and Zmud (1987), p. 240, Chwelos et al. (2001), pp. 317, Chau and Tam (2000), pp. 232, Lee and Shim (2007), p. 719, and Chau and Tam (1997), p. 9

Source: compiled by the author

Competitive pressure is generally perceived having a positively influence on innovation in inter-organizational supply chains. Competitive pressures in the utility industry, e.g. resulting from rivalry among competitor or in particular for the German utility industry resulting from the German energy transition, push companies to adopt and implement new technologies. Competition might be one facilitator to of innovation. The researched technologies might make a contribution to reduce cost and keep the production facilities in the market.[237]

Innovation maturity supports innovation in inter-organizational supply chains. According the stated life-cycle process and stages of innovation, a decreasing perceived immaturity lowers the uncertainty of decision makers and consequently supports innovation.

[237] cf. Premkumar and Roberts (1999), p. 472 and Quetti et al. (2012), p. 318

Industry environment supports innovation in inter-organizational supply chains. The characteristics of the (supplier's) industry in which a SC operates influence the adoption of a technology. Previously stated influencing factors in the environment of supply chain members might can positively influence the adoption of innovation to further promote supply chain collaboration in the inter-organizational sense.[238]

Uncertainty of environment supports innovation in inter-organizational supply chains. Since uncertainty exists due to imperfect information to organization's decision make, higher level of uncertainty drives the need for chaining technology and accelerates adoption rates. Companies in uncertain supply chain environment seek (technological) innovation to improve information exchange, reduce cost resulting in an overall increase in supply chain performance in a collaborative supply network.[239]

Technological fit

The factor 'technological fit' is divided into three variables as described in table 3.

Complexity of an innovation negatively impacts innovation in inter-organizational supply chains.

In reference to the stated definitions of complexity according to Rogers (1983) Karahanna et al. (1999) Kwon and Zmud (1987) as the effort and difficulty an innovation's adoption requests, it perceived as having a negative impact on the implementation and spread of (technological) innovation. Only few indications are given in literature of having a positive influence on innovation's adoption. Related to the comparative research in this thesis, the implementation complexity of one technology (RFID) is more complex than from the other one (bar code). However for both technologies and especially in a relative more complex inter-organizational environment, complexity is expected of having a negative aspect on (technological) innovation and resulting increase in supply chain performance.[240]

Compatibility of an innovation in both technological and organizational meaning, supports innovation in inter-organizational supply chains.

Rogers (1983) defines compatibility as the "degree to which innovation is perceived as being consistent with the existing values, past experiences and needs of potential adopters". Karahanna et al. (1999) explains compatibility of innovation adoption more general as "compatible with what people do".[241] Whereas some authors limit compatibility only to technological aspects, other authors focus more on the existing equilibrium within and between organizations, influenced by an (technological) innovation. In this study and

[238] cf. Gatignon and Robertson (1989), pp. 36, Chang et al. (2008), p. 204-205, and Quetti (2012), p. 318
[239] cf. Patterson et al. (2003), pp. 102-103, Chang et al. (2008), pp. 205, and Kwon and Zmud (1987), p. 240
[240] cf. Karahanna et al. (1999), p. 188, Kwon and Zmud (1987), p. 237-238, Rogers (1983), p. 15, Quetti et al. (2012), p. 320, and Brown and Russell (2007), p. 253
[241] Rogers (1983), p. 15 and Karahanna et al. (1999), p. 188

referring to Quetti et al. (2012), compatibility of (technological) innovation in intra-organizational context is considered and measured in both technological and organizational compatibility.[242]

Table 3. **Measurement construct of factor 'technological fit'**

Factor	Description	Question	References
Complexity (of technology) (-)	Complexity is defined as "degree to which an innovation is perceived as difficult to under-stand and use". (Rogers 1983)	A high complexity of a SCM innovation hinders its adoption, for example due to increasing introduction efforts. (Tec1)	Kim and Garrison (2010), p. 395 Rogers (1983), pp. 14, Karahanna et al. (1999), p. 188, Strüker and Gille (2010), p. 984, and Sharma et al. (2007), p. 3758
Compatibility (of technology) (+)	Literature defined it as "the degree to which IT inn-ovation adoption is compatible with what people do" (Karahanna et al. 1999) - in both technological and organizational ways.	The adoption of a SCM innovation is organizationally compatible with 'what people do'. (Tec2) The adoption of a SCM innovation is technologically compatible with 'what people do'. (Tec3)	Karahanna et al. (1999), p. 188, Kim and Garrison (2010), p. 395, Pfeiffer (1992), pp. 54, Rogers (1983), pp. 14-15, Quetti et al. (2012), p. 320, Iacovou et al. (1995), p. 466, Chwelos et al. (2001), pp. 317, Fichman (2004), pp. 317, Moore and Benbasat (1991), p. 216, Morrel and Ezingeard (2002), p. 53-54, Strüker and Gille (2010), p. 984, Robey et al. (2008), p. 505, Premkumar and Ramamurthy (1995), p. 312, Brown and Russell (2007), p. 253, Cooper and Zmud (1990), p. 131, and Chau and Tam (1997), p. 9
Visible obstacle (-)	Visible obstacle perceived by the decision maker of affects of the adoption of innovative technology. Relevant obstacles for the adoption of innovative technology in inter-organizational supply chains are information system infrastructure and mutual standards.	The organization has people and knowledge available to support a SCM implementation. (Tec4) Visible obstacle hinders the successful implementation of a SCM innovation, e.g. non-availability of IT-infrastructure between supply chain partners, (personal-) data protection, data read errors, missing standards/norms. (Tec5)	Kim and Garrison (2010), p. 395, Chang et al (2008), p. 206-207, Quetti et al. (2012), p. 320-321, Chwelos et al. (2001), pp. 317, Camarinha-Matos et al. (2009), p. 59, Morrel and Ezingeard (2002), p. 53-54, Robey et al. (2008), p. 505, Premkumar and Ramamurthy (1995), p. 310-311, Chau and Tam (1997), p. 9, and Sharma et al. (2007), p. 3758

Source: compiled by the author

Visible obstacle negatively impact (technological) innovation in inter-organizational supply chains.

As stated before, visible obstacles in the maker's understanding might hinder the adoption of innovative technology.

In this thesis, two scales measure the variable 'visible obstacle'. First, the impact of the availability of work force and expertise for supporting technological innovation is measured. Secondly, the impact of visible obstacles, which hinders the implementation of a new SCM

[242] cf. Quetti et al. (2012), p. 320 and Premkumar and Ramamurthy (1995), p. 311

technology, is assessed. Examples are given, such as the non-availability of a flexible and configurable base infrastructure, privacy aspects, data read errors, missing standards/norms.[243]

Product context

The factor 'product context' is divided into four variables as described in table 4.

Table 4. **Measurement construct of factor 'product context'**

Factor	Description	Question	References
Product complexity (-)	Product complexity regarding number of products and suppliers requires additional efforts for implementing a new technology in intra-organizational SCM.	Your large number of supplier for materials increases the complexity of a SCM innovation. (Pro1) Frequently changing actions of main suppliers increase the complexity of a SCM innovation. (Pro2)	Wong et al. (2011), p. 198-199
Product availability (+)	The product availability is a key factor in the maintenance, repair and overhaul processes. Especially in the electricity generation, shortage costs (might result in the unavailability of generation unit) are main cost drivers.	The product availability, relevant for maintenance, repair and overhaul processes, can be increased by a SCM innovation. (Pro3)	Wong et al. (2011), p. 198-199
Product life-cycle management (+)	Product life-cycle management is a key task in maintenance, repair and overhaul processes. A new SCM technology might support or add new services to the product life-cycle management.	The product life-cycle management of spare parts - e.g. management of repairs, installation points and activation, is supported by a SCM innovation. (Pro4)	
Product attributes (-)	Product attributes have a high impact on the benefits of the adoption of new SCM technologies. Consumables (esp. throw-away products) and low-value products are less applicable for a technological innovation investment.	Low-value consumables are less relevant for a SCM innovation. (Pro5)	Cooper and Zmud (1990), p. 130-131

Source: compiled by the author

243 cf Chau and Tam (1997), p. 9, Kim and Garrison (2010), p. 395, Sharma et al. (2007), pp. 3758, Chang et al. (2008), p. 206-207, and Quetti et al. (2012), p. 320-321

Product complexity negatively impacts innovation in inter-organizational supply chains. An increasing fluctuation in product characteristics and number of suppliers requires additional efforts for implementing a new technology in intra-organizational SCM. Consequently, this variable is measured by the fluctuation rate of products and suppliers and their impact on innovation adoption.

Product availability negatively impacts innovation in inter-organizational supply chains. As stated before, literature research the causes and effects, direct as well as indirect effects, of shortage cost. In this thesis, the respond is questioned regarding the impact of supply chain innovation on product availability, relevant for maintenance, repair and overhaul processes.[244]

Product life-cycle management supports innovation in inter-organizational supply chains. An innovative product life-cycle management might add a relative advantage to the integrated supply chain by providing information about the components quality and reliability levels, next point usages, This information allows the operator to optimize production and maintenance processes and therefore reducing production and maintenance costs. The repair processes, which can be differentiated into ordinary and emergency procedures, and the re-use of the components can be stated in the product life-cycle management, which also part of the supply chain management covering disposition, stock keeping and transportation of the product.[245]

Product attributes negatively impact innovation in inter-organizational supply chains. The perceived quantitative and qualitative benefits resulting in an overall increase of supply chain performance are influenced by product attributes. Cooper and Zmud (1990) researched the impact of violation of material requirement planning and number of bill-of-materials levels in the implementation of an (technological) innovation. Consumables, in particular esp. throwaway products and low-value products are less applicable for an (technological) innovation investment. In retail industry and in particular for the fast-moving consumer goods industry the consumer behaviour to out-of-stock situations and its related cost is researched for decades.[246]

[244] cf. Öner et al. (2010), p. 617
[245] cf. Abboud and Daigle (1997), p. 578
[246] cf. Cooper and Zmud (1990), p. 130-131 and Aastrup and Kotzab (2010), p. 160-161

Supply chain readiness

The factor 'supply chain readiness' is divided into four variables as described in table 5.

Table 5. **Measurement construct of factor 'supply chain readiness'**

Factor	Description	Question	References
Bargaining power (+)	The bargaining power of some market actor influences the diffusion process - slowing or accelerating it.	The bargaining power of a supply chain partner positively influences the diffusion of a SCM innovation. (Scr1)	Brown and Russell (2007), p. 254, Iacovou et al. (1995), pp. 480, Quetti et al. (2012), p. 322-323, Chwelos et al. (2001), pp. 317, Carter et al. (2007), p. 47, Hart and Saunders (1997), p. 28, Klein and Rai (2009), pp. 742, Niemeyer et al. (2003), p. 8, Son et al. (2008), p. 44, Premkumar and Ramamurthy (1995), pp. 310, and Sharma et al. (2007), p. 3758
Initiator (+)	The presence of an initiator facilitates (technological) innovation.	One market actor initiates the adoption of a SCM innovation. (Scr2)	Bruque (2007), p. 244, Patterson et al. (2003), p. 101-102, Quetti et al. (2012), p. 323, Brown and Russell (2007), p. 254, and Karahanna et al. (1999), pp. 188, and Premkumar and Ramamurthy (1995), p. 312
Trust (+)	Trust and faith between supply chain members are key elements of the transaction climate and the adoption of innovation.	The presence of trust and confidence to your SC partners facilitates information sharing and adoption of a SCM innovation. (Scr3)	Cheung et al. (2009), p. 52, Patterson et al. (2003), p. 101-102, Premkumar and Roberts (1999), p. 481, Chwelos et al. (2001), pp. 317, Hart and Saunders (1998), p. 97, Niemeyer et al. (2003), p. 8, Robey et al. (2008), p. 505, and Fynes et al. (2005), p. 3315
Partner readiness (+)	Trading partner readiness (ability and willingness) is fundamental for (technological) innovation in an intra-organizational dimension.	Formal and informal procedures, routines, norms and conventions shared in the cooperation support the implementation of a SCM innovation. (Scr4)	Cheng et al. (2014), pp.176, Chwelos et al. (2001), pp. 316, Brown and Russell (2007), p. 254, Patterson et al. (2003), p. 100-101, Wen et al. (2009), p. 25, and Quetti et al. (2012), p. 323-324, Fichman (2004), pp. 317, Lee and Shim (2007), p. 719, Morrel and Ezingeard (2002), p. 53-54, Robey et al. (2008), p. 502, and Rosas and Camarinha-Matos (2009), p. 4716
Inter-organizational dependencies (+)	Dependencies refer to already existing relation-ships, such as inter-firm contracts and influenced by frequency, ration and duration of collaboration.	Existing SC relationships/ partnership support the adoption of a SCM innovation. (Scr5)	Cheng et al. (2014), pp.176, Premkumar and Roberts (1999), p. 472, Chang et al. (2008), p. 205, Quetti et al. (2012), p. 324, Kwon and Zmud (1987), p. 241, Chwelos et al. (2001), pp. 317, Clemons and Hitt (2004), pp.104, Klein and Rai (2009), pp. 742, Son et al. (2008), p. 44, and Premkumar and Ramamurthy (1995), pp. 309

Source: compiled by the author

The author considers 'supply chain readiness' as a fundamental determinant in the decision process of adopting innovation in inter-organizational supply chain management.

Bargaining power supports innovation in inter-organizational supply chains. As shown in recent literature, bargaining power has pushed technological innovation in certain industries. In the retail industry, e.g. the US-located Wal-Mart and the German Metro Group, applied different tactics to push innovation adoption within its supply chain. In the German electricity generation industry and its changing environment, the bargaining power of the big market actors is diminishing. Nevertheless, the cost pressure might force some actors to use supply chain collaboration and technological innovation to gain competitive advantage of its integrated supply chain.[247]

The indicator 'initiator' impact positively innovation in inter-organizational supply chains. As stated in the previous variable bargaining power, the presences of an initiator might facilitate (technological) innovation. The initiator might also use its influence on other organizations for pushing technological innovation, even if the supply chain member perceives the innovation negatively.[248]

Trust impact positively impacts innovation in inter-organizational supply chains. A positive transaction climate between the supply chain members might enhance and motivate the organizations to share information, improve inter-organizational coordination and cooperating.[249]

Partner readiness impacts innovation in inter-organizational supply chains. Literature differentiates between the technical ability and the willingness to adopt innovation. In this this a positive influence of the partner's ability and willingness are expected on technological innovation in the inter-organizational dimension. Previous researches indicate that a high level of trust is necessary for the adoption of innovation as well as supply chain collaboration.[250]

Inter-organizational dependencies impact positively (technological) innovation in inter-organizational supply chains. As stated before, dependencies refer to already existing supply chain relationships, such as inter-firm contracts and are influenced by frequency, ration and duration of collaboration. Kwon and Zmud (1987) state a positive correlation between information sharing and experience exchange between organizations in the adoption of innovative technologies. In this thesis, inter-organizational dependencies are expected to have positive influence on technological innovation in inter-organizational supply chains. Within the measurement of this variable, it will be highlighted on strategic partnership to suppliers as an initial step in the adoption of innovation.[251]

[247] cf. Iacovou et al. (1995), pp. 480, Brown and Russell (2007), p. 254, and Quetti et al. (2012), p. 322-323
[248] cf. Patterson et al. (2003), p. 101-102, Quetti et al. (2012), p. 323, and Brown and Russell (2007), p. 254
[249] cf. Patterson et al. (2003), p. 101-102 and Hart and Saunders (1998), p. 98
[250] cf. Chwelos et al. (2001), pp. 316, Brown and Russell (2007), p. 254, and Patterson et al. (2003), p. 100-101
[251] cf. Kwon and Zmud (1987), p. 241 and Chang et al. (2008), p. 205

Supply chain performance

The construct 'supply chain performance' is divided into two variables as described in table 6.

Table 6. **Measurement construct of supply chain performance**

Factor	Description	Question	References
Supply chain effectiveness and supply chain efficiency	Measurement the effect of a new SCM technology in inter-organizational supply chains - regarding SC effectiveness and efficiency. Literature defines it also as the relative advantage, defined as "degree to which innovation is perceived as better the idea it supersedes". (Rogers 1983)	Late, damaged and incomplete orders are eliminated after implementing a SCM innovation. (Scs1) The ability to deliver additional value-added services increases by implementing a SCM innovation, e.g. track and trace. (Scy1) The ability to quickly respond to and solve problems increases by implementing a SCM innovation. (Scy2) The ability to deliver products precisely on-time increases by implementing a SCM innovation. (Scs2) The ability to deliver products precisely quantities increases by implementing a SCM innovation. (Scs3) The ability to deliver shipments of variable size on a frequent basis increases by implementing a SCM innovation. (Scy3) The overall supply chain cost decreases by implementing a SCM innovation. (Scy4) The safety stock levels throughout the supply chain decreases by implementing a SCM innovation. (Scs4)	Zelbst (2012), pp. 338, Zelbst et al. (2010), p. 585, Green et al. (2009), p.163, Wong et al. (2011), p. 198-199, Rogers (1983), pp. 14, Cragg and King (1993), p. 53, Brown and Russell (2007), pp. 252, Chau and Tam (2000), p. 235, Chwelos et al. (2001), pp. 317, Igbaria et al. (1997), p. 282-283, and Chau and Tam (1997), p. 9

Source: compiled by the author

The dependent variable 'supply chain performance' is measured by the construct of supply chain effectiveness and supply chain efficiency - according to the differentiation of effectiveness and efficiency by Drucker, who states effectiveness as doing the right things and efficiency as doing things right.[252] Four questions each are assigned to both supply chain effectiveness (variable Scs) and efficiency (variable Scy).

Supply chain effectiveness is operationalized by late, damaged and incomplete orders are eliminated, by the ability to deliver products precisely on-time increases, by the ability to

[252] cf. Drucker (1955), p. 117 and Drucker (1963), p. 54

deliver products precisely quantities and by the safety stock levels throughout the supply chain.

Supply chain efficiency is operationalized by the ability to deliver additional value-added services, by the ability to quickly respond to and solve problems, by the ability to deliver shipments of variable size on a frequent basis and by the overall supply chain cost.

The measurement scale for the dependent variable 'supply chain performance' is adopted from previously developed scales in scientific researches. For example, Zelbst et al. (2012), Zelbst et al. (2010) and Green et al. (2009) applied similar scales and assessed its validity and reliability.[253]

General questions

In addition, general questions are implemented as described in table 7.

The general questions applied in this thesis are relevant to assess the background of the respondent.

The core competency indicates the industry sector of the respondent's company. The results regarding SCM innovation may differ in each industry sector. The previously stated basic population and the stated sample size, includes next to the electricity generation industry also companies, who generate electricity for the different core competency. As stated in appendix 21, companies also refer for example to the chemical, automotive and paper industry.

The next three questions address the background of the respondent. The position of the respondent, years within the position as well as years in the industry characterise the respondent's experience and angel of view on innovation in supply chain management.

The following question refers to the status and potential reasons for not adoption of technological innovations in relation the innovations comparative researched in this thesis.

In the final question of the online survey, the respondent can enter his contact details to receive summary of results.

In relation to the additional survey participants, the last two stated question in table 7 are added to the questionnaire. The question 'Member of supply chain energy generation' assesses whether the respondent belongs to the basic population of this thesis supplemented by the question regarding the respondent's section of branch according to Federal Statistical Office. The selected section B „mining and quarrying", section C „Manufacturing", section D „gas, steam and air conditioning supply, section E „water supply, sewerage, waste management and remediation activities and section F „construction". The author also adds one free text field for adding other sections by the respondent.

[253] cf. Zelbst (2012), pp. 338, Zelbst et al. (2010), p. 585, and Green et al. (2009), p.163

The general questions applied in the questionnaire are described in the following table 7.

Table 7. **Measurement construct of general questions**

Factor	Description	Question	References
Core competency	The core competency indicates the industry sector of the respondent's company.	Is the operation of the existing power plant the core competency (electricity production) of your company? (GQ1)	
Position of the respondent	The position of the respondent within the company may indicate the point of view on some issues of SCM innovation.	Please indicate your management level within the company: - Manager (supply chain manager / purchasing manager / operations manager) - Supervisor (directly supervise supply chain / purchasing / operating activity) - Worker (supply chain / purchasing / operating activity) - other activity - not specified (GQ2)	Mostaghel et al. (2012), p. 2440
Years in position of the respondent	The years in position of the respondent within the company may indicate the experience on some issues of SCM innovation.	Please indicate the time-period within the management level (in years): 0-1 2-5 6-10 11-15 16 and more (GQ3)	
Years in industry	The years within the industry of the respondent may also indicate the experience on some issues of SCM innovation.	Please indicate the time-period within the industry (in years): 0-1 2-5 6-10 11-15 16 and more (GQ4)	
Status of innovation adoption	The status of innovation adoption of these two SCM innovations represents the experience regarding its benefits and costs.	Please indicate your status of company's adoption of technological innovation in the inter-organizational supply chain: (for bar code and RFID) - Non-adopter - Intra-organizational adopter - Inter-organizational adopter (GQ5)	

Source: compiled by the author

Table 7. (continuation) **Measurement construct of general questions**

Factor	Description	Question	References
Reasons for not adoption of technological innovation	The reasons for not adoption these two SCM innovation may highlight particular shortcoming for these SCM innovations.	Please name (multiple) reasons for not adopting SCM innovation in the inter-organizational supply chain: (for bar code and RFID) - Lack of awareness of the concept - Lack of time - Cost of investment is too high - Unclear scale of beneficial results - Reading data is not accurate - Lack of technological implementation standards - Consideration of (personal-) data protection - Companies in the inter-organizational supply chain are not willing to cooperate - Political consideration of labour organization - Others (GQ6)	
Contact detail for summary of results	Respondent may enter the contact details for receiving a summary of results.	Thanks you for your participation! I will be glad to email you a summary of results. If you have any questions, please don't hesitate to contact me (EMAIL) You can enter your Email-address below: (GQ7)	
Member of supply chain energy generation	Determination of the respondent's' affiliation to the supply chain of the electricity generation industry.	Is your company a supply chain partner of the industry electricity generation? - yes - no (GQ8)	
Section of branch of trade	Section of branch of trade of the supply chain partner in the electricity generation industry.	Please indicate the company's industry segment: (Relevant) Sections of branches of trade according to Federal Statistical Office: - Mining and quarrying (Section B) - Manufacturing (Section C) - Electricity, gas, steam and air conditioning supply (Section D) - Water supply, sewerage, waste management and remediation activities (Section E) - Construction (Section F) - Other sections: (GQ9)	

Source: compiled by the author

In summary of chapter two, the author sates the research methodology and the research design in relation to the theses for defence regarding managerial impact factors of innovation in inter-organizational supply chains, research in the underlying German electricity generation industry.

The author identifies bar code technology as still relevant for innovation in inter-organizational supply chains. Next to the stated limitations of this enabling technology, the author states also the potential for successfully meeting the today's goals of future supply chain management.

The author clearly outlines the innovative potential of RFID technology as an enabling technology for innovation in inter-organizational supply chains based on the current state of the art of business research as well as benefit and cost models. The author identifies challenges of today's supply chain management, RFID technology has the potential to improve, such as inventory inaccuracy, the bullwhip effect and replenishment policies, indicating the potential for meeting requirements of concepts for future inter-organizational supply chain management.

The supply of electric power is one backbone of modern economies. The German market design and its actors are in the middle of an adaption process under the new macroeconomic circumstances of the transition of electricity power supply including the phase-out of nuclear-fuel energy and intensive usage of renewables – the so-called German 'Energiewende'. The author identifies supply chain innovation as necessary for the upcoming transition process of the current supply chain management process to a future process in order to meet the upcoming predatory market competition. Currently, most supply chain transactions in the German electricity power generation industry are performed with media discontinuity. This means the physical flow of material is still performed paper-based in form of an attached delivery note. The implementation of innovations and potential underlying enabling technologies in the supply chain might increase supply chain performance and therefore decrease cost of maintenance and consequently cost of operation of the power-generating unit.

Casual research applying sequential triangulation and comparative method is derived as main methods of research in relation to the stated theses for defence. In the first stage of the data collection, qualitative research is used to identify the actual stage of research. In addition to a theoretical analysis of literature, semi-structured interviews with experts are carried out. Based on the results and findings of the first stage, a data collection using the quantitative research method self-completion questionnaire survey is planed and executed. Hereby, the author uses comparative research method regarding the stated enabling technologies within supply chain innovation testing the stated hypotheses within the defined basic population in order to answer the research question.

In the next chapter, the empirically gathered data will be analysed and the results of research towards managerial impact factors for innovation in inter-organizational supply chains will be stated. All stages of the research process are performed on the basis of actual research standards such as the ethic codexes.

3. Empirical Data Analysis and Results of Research towards Managerial Impact Factors for Supply Chain Innovation

The chapter three covers the research results and their interpretation.

For both research methods, the research results are exhibited form the empirical data collection process. The results of the qualitative research method are described and analysed according to the stated method of meaning condensation. The results of the quantitative research method are conditioned by applying multivariate statistics including structural equation modelling for analysing the empirical data.

The reflection and interpretation of the research results is conducted and clearly linked to the pervious researches and parts of this thesis including the stated theses for defence.

3.1. Interviews with experts supportive for defined managerial support factors

The main findings of the semi-structured interviews with experts are stated in the following. The main findings include aspects regarding the researched managerial factors for innovation in inter-organizational supply chain management as well as aspects regarding the relevant innovative enabling technologies studied by comparative research methodology in this thesis.

Kvale and Brinkmann (2009) highlight that qualitative research methods and in particular interviews involve different ethical issues than questionnaire surveying.[254] Referring to these specific ethical standards in qualitative research, the results of the semi-structured interview with experts are stated among the required and by the interviewees agreed level of confidentiality.

Factor ‘organizational characteristics’

The factor ‘organization characteristics’, covering ‘financial resources’, ‘top management’ and ‘company size’, is reflected upon addressing different types and perspectives to business organizations within the interviews.

- The sub-factor ‘top management’, such as managerial enthusiasm, is clearly described the major factor and driver of innovation and underlying enabling technologies.

  Interviewees described business situations in which the implementation of an innovation has been pushed inside the organization by the top management. In one reported case and even without clear perceived advantages, managerial enthusiasm supported the adoption and implementation of an innovative technology. The top management established a new department, which reported directly to the board, and clearly expressed the company’s

[254] cf. Kvale and Brinkmann (2009), p. 72-73, see also chapter 2.1 and applied ethical standards of the research.

will to invest and research the impacts of the innovation within supply chain management. The team later developed new ideas of usages that have not been though at first.

- The sub-factors 'financial resource' and organizational 'size' are highlighted not only by interviewees from multi-national DAX[255] companies as a supporting factor for innovative behaviour in inter-organizational relationships. Especially 'financial resources' as a result of the organization's size are identified as useful for the development and implementation of innovations and enabling technologies, preferably in further developed stadium.

Factor 'technological fit'

The factor 'technological fit', consisting of the indicators 'complexity', 'compatibility' and 'visible obstacles', is off central relevance in the interviews due to the applied comparative research design in this thesis.

- The sub-factor 'compatibility' is strongly stressed by almost all interviewees. It is highlighted that innovation request a need for re-design of processes. According to the stated finding of Yücesan (2007) and illustrated in appendix 4, supply chain management requires the careful planning and close coordination of three types of flows – material, information and financial – by optimizing the three key building blocks - process, organizational structure and enabling technologies.[256] The interviewees state a clear need for re-designing all aspects of supply chain management while implementing an innovation such as an innovative enabling technology. The benefits of innovations can only be utilized by re-thinking and re-arranging all three key building blocks by all members participating in the supply chain collaboration.

  The interviewees clearly described the necessity for choosing the adequate innovative approach, e.g. an enabling technology in form of an Auto-ID technology, to each supply chain. Interviewees proposed that within the utility and in particular the electricity generation industry, the focus of supply chain innovation should be concentrated initially on high-value and high turnover ratio items, such as operational relevant spare parts instead of the so called consumables (C-items) or even highly strategic parts with even no turnover and very detailed maintenance records in internal and external ERP-systems. The Interviewee from ThyssenKrupp introduces the mainly intra-organizational process innovation of tracking steel – slabs as the main raw materials are tracked by RFID technology between company's plants in Brazil and Europe/U.S. with significant monetary savings in the overall supply chain management.

[255] The DAX is the German blue chip stock market index consisting of the 30 major German companies.
[256] cf. Yücesan (2007), p. 130-131

However, inter-organizational innovations supported by RFID technology remain mostly still individual projects in the medical, automotive network (RAN - RFID-based Automotive Network) or food and retail industry.

- As a visible obstacle regarding the factor 'technological fit' in inter-organizational supply chain innovation, the interviewees mention the need for standards and the industry's compliance to these standards.

  Interviewees, such as the association EuroData Council, representing the Federal Republic of Germany in organizations like the International Standardization Organization (ISO), as well as the FIR (Institute for Industrial Management) at the RWTH Aachen University, highlighted the necessity for the industry to stick to available and proven standards, available also in inter-organizational supply chain settings.

  The interviewee from the organization GS1 puts it in a simple form by stating "stick to standards instead of creating a new ones" for each inter-organizational supply chain integration. One example mentioned in the interviews is the previously stated European Directive 2011/62/EU in combination with the German 'securPharm' initiative in cooperation of the pharmacy industry and the international organization GS1.

  On the other hand, such a standardisation in the automobile industry seems to be not possible, because automobile companies want to stick to their numbering standards due to after-market sales conditions around the world. A three-year project of GS1 and EECC for the standardization of numbering has not been successful.

  Overall and in relation to the in this thesis researched industry, technological standards for innovation for inter-organizational supply chain are available and should not limit or even hinder innovation.

- A further visible obstacle mentioned in actual state of the art literature and therefore been discussed in the interviews, are security issues of innovation enabling technologies, such as Auto-ID technology.

  Security aspects regarding the implementation of bar code and even RFID technology in inter-organizational supply chains in the utility industry are not seen as critical by the interviewed experts. In this particular supply chain, a private customer is not involved or in touch with a bar coded or tagged product. The interviewees consider an implementation of bar code and RFID technology in a supply chain between electricity power generation companies, its suppliers and its (mostly) internal than external business customers as not critical regarding information security.

Factor 'environmental characteristics'

The factor 'environmental characteristics', covering aspects of 'competitive pressure', 'innovation maturity', 'industry environment' and 'uncertainty of environment', is dominated in the interviewees by the sub-construct of 'innovation maturity' regarding the two relevant enabling technologies of supply chain innovation.

- The indicators 'competitive pressure' as well as 'uncertainty of environment' are clearly identified by the interviewees as a driving force of innovation. Especially interviewees from the industrial organizations state the actual and ongoing changes in the utility industry as well as the increasing cost pressure in the electricity generation industry as influencing factors.
- The sub-factor 'innovation maturity' was discussed in all interviews in detail according to the researched innovative technologies.

  Bar codes have the innovative maturity of the technology and are still one element the future technological approaches in supply chain management. One-dimensional bar codes are not able to identify all logistic items or even all things within the Internet of Things concept. Two-dimensional bar codes can solve this technological limitation and represent a comparable option to RFID technology. Interviewees, especially from the research organizations and consultancies (e.g. GS1, tacNology, EuroData), identify data matrix codes as an already existing enabling technology to support supply chain innovation and identify this approach available on all products as possible – instead of RFID technology. One interviewee (EECC) prefers bar code a little less compared to RFID technology.

  Bar code technology meets the requirements of industrial concepts. Today's industrial and economic-political conceps, such as the 'Industrie 4.0' concept, will base on various Auto-ID technologies. Due to the described necessity of applying the proper Auto-ID technology for each supply chain application, bar code as well as RFID technology will be part of these concepts. Interviewees (e.g. EECC) stated the limitations of bar codes within the 'Industrie 4.0' concept, which ultimately contains smart supply chain objects with the capacity to 'think'.

  As one approach for establishing innovation maturity in this context, interviewees clearly recommended a phased (step-by-step) introduction of the implementation of innovation. The first step of an Auto-ID technology implementation should focus on bar code technology in to order to establish bar code technology for supporting inter-organizational processes. In a second step, RFID technology should be tested with redesigned processes.

  The European EPC Competence Centre (EECC) predicts a near future penetration of RFID technology on loading equipment level within supply chain management. By tagging carriers within closed loops carrier supply chains, such as carriers at logistic operator Deutsche Post DHL, the Metro Group within its food industry subsidiary, or even tagging the regular euro-pallets, RFID technology is applied as a central element within the supply chain's flow of materials and information. This might be the starting point for further services or products and a wider adoption of RFID technology in supply chain management. However, the RFID tagged pallets need to be used by a critical number of companies allowing a further spread of theses palettes in integrated supply chains. Overall, the interviewees clearly identified the factor 'innovation maturity' as one major impact factor on the environmental and entire innovation decision process.

Initiator 'supply chain readiness'

The construct 'supply chain readiness' includes next to 'bargaining power', 'initiator', 'trust' and 'inter-organizational dependencies' the indicator 'partner readiness'.

- Based on the stated finding of the necessity for re-thinking and potentially re-designing key building blocks of the supply chain, interviewees recommend that the re-designing process should also prove a win-win situation for all members of the supply chain.

  Supply chain members with high bargaining power, who might act as an initiator of innovation, should show their partners how to lift overall process/cost advantages. Within one industry, interviewees recommended to sign service level agreement with suppliers to gain the supply chain member's confidence in a win-win situation.

  As examples for acting as an initiator of an innovation, interviewees state their request of innovation standards for products, such as RFID-tagged server racks, or Auto-ID supported Kanban processes.
- The sub-factor 'initiator' is identified in several interviews as one major managerial impact factor for innovation in the supply chain.

  One reason for the limited penetration of a particular innovation is the imbalance of advantages for the members of a supply chain. Interviewees highlight the challenges for the pioneer of implementation an innovation in the specific supply chain. One question for example regarding RFID technology is mostly raised, which supply chain member is investing first to start the innovation's adoption process. Organizations such as GS1 try to promote the communication between all supply chain members regarding the overall benefits of an enabling Auto-ID technology.
- The sub-factor 'trust' is supported by all interviewees as one keystone for inter-organizational supply chain innovation. One interviewee formed a "triangle of Auto-ID technology", consisting of identifying and gathering information about an object and

exchange the information across the supply chain, e.g. by the available standard for EDI (electronic data interchange), the EPCIS standard.

Impact and measurement scale of supply chain performance

Overall, the interviewees agree to the in this thesis applied measurement scale of supply chain performance regarding the impact of managerial factors of innovation in inter-organizational supply chains. The approach of utility theory is identified as one key element in the business managers' decision-making process during the evaluation of an (positive) effect of adopting an innovation in system of supply chain management.

Main findings for the measurement of supply chain effectiveness and efficiency in accordance to the comparative research approach are stated in the following.

- The measurement indicators regarding supply chain effectiveness in question 25, 28, 29 and 32 in the questionnaire are characterized as valid and reliable by the interviewees.

  The effectiveness of both technologies is identified especially by the interviewees form research organizations and consultancies as meeting today's operational requirements. The in actual researches and white papers stated obstacles for RFID technology, such as the read range, is solvable. Further innovation within RFID technology, e.g. by lowering the energy rate, might promote its application in supply chain management and even enable the Internet of Things concept.
- The measurement indicators regarding supply chain efficiency in question 26, 28, 30 and 31 in the questionnaire are also characterized as valid and reliable by the interviewees.

  One factor of main interest in the interviews is question 31 of the questionnaire and the impact of innovation on the cost elements of the supply chain. Most interviewees from industrial companies would require a positive return on investment calculation in the role of the decision maker or any kind of managerial support from top management as stated before. Within this return on investment calculation, all interviewees identify bar code technology as uncritical whereas RFID technology and in particular the costs of tags are identified as critical within supply chain innovation. In contrast, one interviewee (EECC) even states, that by a new UHF tag standard, the cost range of 5 Cent per tag - seems to be possible.

  Within such an efficiency evaluation, the results from a process re-design or even the availability of offering additional value-added services to the customers by implementing an innovation need to be proven monetarily.

  Three interviewees from research and public organizations illustrate the example of a process re-design of the regular inventory in an automatic or even semi-automatic way by applying RFID technology. Industrial interviewees are irresolute about the approval by the organization's Certified Public Accountant for such a re-designed process innovation.

- The interviewees state unanimous that the hype of RFID technology is over. Interviewees recommend selecting the appropriate Auto-ID technology for each supply chain.

  The fast moving consumables industry has been a pioneer for RFID technology as an enabling technology for supply chain innovation. Major market actors acted as an initiator with high bargaining power against suppliers. However the expected savings of labour staff in the fast moving consumables industry did not realize as expected (stated by BSI, tagNology, EECC).

  Market actors with a dominant bargaining power acted as pioneers for innovation implementation, for example for RFID technology implementation the German REWE Group in the food and the German DHL in postal industry / supply chain.

  The author of thesis receives in-depth knowledge about the reasons of failure and obstacles of supply chain innovation by applying RFID technology as an enabling technology. Some former initiators also refused to discuss managerial impact factors for supply chain innovation within this thesis.[257]

  The interviewees indicate the need for assessing the benefits and cost of the Auto-ID technology according to the kind of material and its underlying supply chain. Within the electricity power generation industry, the supply chain for critical parts for power plants, which have to be on stock ensuring the availability for maintenance work on plant side within short notice as well as due to further quality management issues, might be in the strategic focus for improving supply chain performance and reliability by implementing a supply chain innovation and underlying enabling technology.

The author analyses the empirical data from the quantitative research method and derives the results in the next sub chapter. In chapter 3.3., the author interprets the research results from both research methods in connection with previous research results.

[257] cf. DHL Customer Solution & Innovation (2014), private communication with department DHL Customer Solutions & Innovation Marketing & Communications from the DHL Innovation Center, Troisdorf-Spich, Germany

3.2. Self-completion questionnaire survey results of managerial impact factors

The self-completion questionnaire is analysed by the multivariate analyis technique of structural equation modelling using partial least squares (PLS), which is performed in the software Smart PLS. In reference to the applied comparative research approach, the author calculates a structural equation model for each treatment: 'in general', 'bar code' and 'RIFD'. The relevant figures and tables for each structural equation model are also stated in the appendixes 22 to 40.

As a basis for the model validation, the quality of empirical data gathered during the data collection phase needs to be verified. In this thesis, the author collects 110 questionnaires. Due to the stated empirical data collection phase, commonly applied criterion of analysis, such as the response rate or the nonresponse bias, are of less relevance in this research.

In reference to the stated research model, including the research construct and the quantity of empirical data, the author chooses on the basis of an extensive literature review a variance-based instead of a covariance-based analyse technique for structuring equation modelling.[258]

The results are stated covering the assessment of the reflective measurement as well as formative measurement model and by the assessment of the structural model. In detail, the author analyses the criterion R Square, f Square, composite reliability and Cronbach's Alpha. The variants of answer 'in general' and both variants 'bar code' as well as 'RFID' technology are successively assessed.

Applying structural equation modelling for answer variant 'in general'

The author applies for the assessment of the structural model the criterion R Square and Cohen's f Square. The author uses for assessing the stated quality criteria reliability and validity the traditional Cronbach's alpha and the alternative measure composite reliability.

R Square is the first essential criterion for the assessment of the PLS structural model equation measuring each endogenous latent variable's coefficient of determination. In other words, R Square measures the relationship of a latent variable's explained variance to its total variance. According to literature, values of approximately 0.670 are considered as substantial, values around 0.333 as average and values of 0.190 as lower or weak.[259]

In appendix 22, the PLS structural equation model of the answer variant 'in general' including R Square and its loadings is stated, in figure 8 and appendix 25 R Square and R Square adjusted are illustrated.

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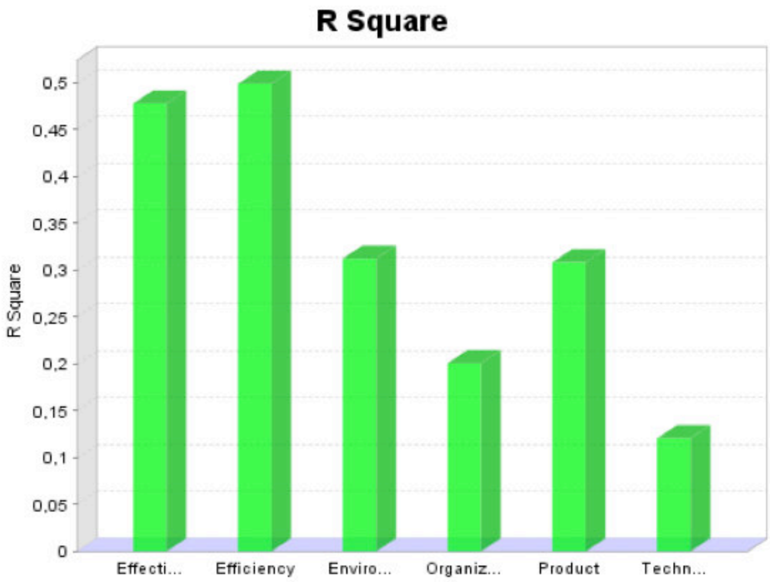
[258] Please see also comparisons of variance and covariance based analyse techniques and software tools regarding SEM (Niztl (2010), p. 20 and Urbach and Ahlemann (2010), pp. 13).

[259] cf. Nitzl (2010), p. 32-33 and Urbach and Ahlemann (2010), p. 21



	R Square
Effectivness	0,478
Efficiency	0,499
Environment	0,313
Organization	0,201
Product	0,309
Technology	0,121

Source: compiled by author. Analysis is based on 110 responses to a questionnaire survey (November 2014 to February 2015) from supply chain members of the German electricity power generation industry.

Figure 8. **Variant 'in general' – R Square**

In the model 'in general', the R Square is for the variable 'organizational characteristics' (Org) 0.201, 'environment characteristics' (Env) 0.313, 'technological fit' (Tec) 0.121, 'product context' (Pro) 0.309, 'supply chain effectiveness' (Scs) 0.478 and 'supply chain efficiency' (Scy) 0.499. The variable Org consists two and the factors Tec and Pro consist each one indicator with a negative loading, which indicates a negative impact on the adoption of supply chain innovations in inter-organizational supply chains, which also explains a lower model fit assessment criterion of R Square.

The criterion R Square adjusted, a modified version of R-Square adjusted for the number of predictors in the model, confirms the stated results of R Square due to only very small differences between both criterions. R Square adjusted, always lower than R Square, is for Org 0.194, Env 0.306, Tec 0.113, Pro 0.302, Scs 0.458 and Scy 0.480.

Overall, the model fit can be stated as substantial to good and the model has a good level of explanatory power.

The path coefficients between the models latent variables are analysed in relation to the algebraic sign, the magnitude and significance and are stated in appendix 23 and 24.

The path magnitude indicates the strength of the relationship between two latent variables and should exceed 0.100 to account for a certain impact within the model. In order to determine the level of significance, resampling techniques of bootstrapping including the p- and t-values are applied. The standardized p-values around 1 and -1 indicate a weak influence of the casual interconnection, whereas values between 0.2 and -0.2 are identified as highly significant. In addition, t-values, resulting from the bootstrapping approach, equal or greater than 1.65 indicate an error probability of 10 percent whereas values equal or greater than 1.96 indicate an error probability of 5 percent and therefore a higher significance.[260]

In the model 'in general', the path coefficients between the inductive factors 'supply chain readiness' and the four stated factors of innovation adoption are high and indicate a strong impact. The same impact can be stated for the five indicators of 'supply chain readiness'.

The path coefficients between the independent and the dependent variable indicate a certain impact. The coefficients for Org-Scs and Env-Scy are marginal lower as the stated levels in literature. The factor 'environment' indicates a negative impact on supply chain effectiveness with a value of -0.017. As stated above, three indicators also show negative algebraic signs and indicate a negative impact on the adoption of supply chain innovation in inter-organizational supply chain.

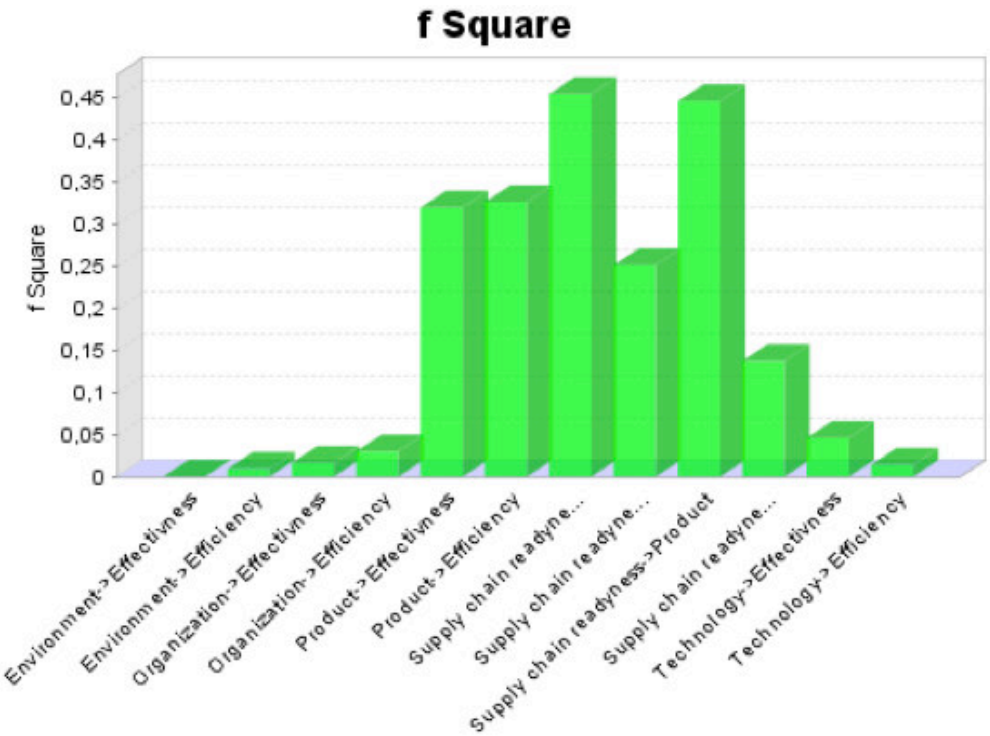
The p-values and t-values of the inductive variable 'supply chain readiness' and its indicators can be all stated as significant – all p-values are between 0 and 0.03 and all t-values are greater than 5.458. The four independent variables Org, Env, Tec and Pro have a lower significant impact on the depended variables Scs and Scy, except the interconnection Tec-Scs (p-value 0,102, t-value 1,64), and the impact of Pro on Scs as well as Sys with p-values of 0 and t-values indicating an error probability of 5 percent.

The indictors Org5 (company's revenue), which most respondent refused to state, Tec5 (visible obstacle) and Pro5 (products attributes) indicate a negative impact but the p- and t-values indicate a less significance influence within the model.

F Square is applied by the author for evaluating the effect size in the structural equation model. The Cohens's f Square measures if an independent latent variable has a substantial impact on a dependent variable by calculating the increase of in R Square of the latent variable to which its path is connected, relative to the latent variables proportion of unexpected variance. Literature states that values of 0.020, 0.150 and 0.350 indicate the predictor variable's low, medium, or large effect on the structural model.[261]

[260] cf. Nitzl (2010), pp. 29 and Urbach and Ahlemann (2010), p. 21

[261] cf. Urbach and Ahlemann (2010), p. 21 and Nitzl (2010), p. 34-35



	Effectivness	Efficiency	Environment	Organization	Product	Supply chain readyness	Technology
Effectivness							
Efficiency							
Environment	0,000	0,010					
Organization	0,017	0,030					
Product	0,320	0,326					
Supply chain readyness			0,455	0,252	0,446		0,138
Technology	0,046	0,014					

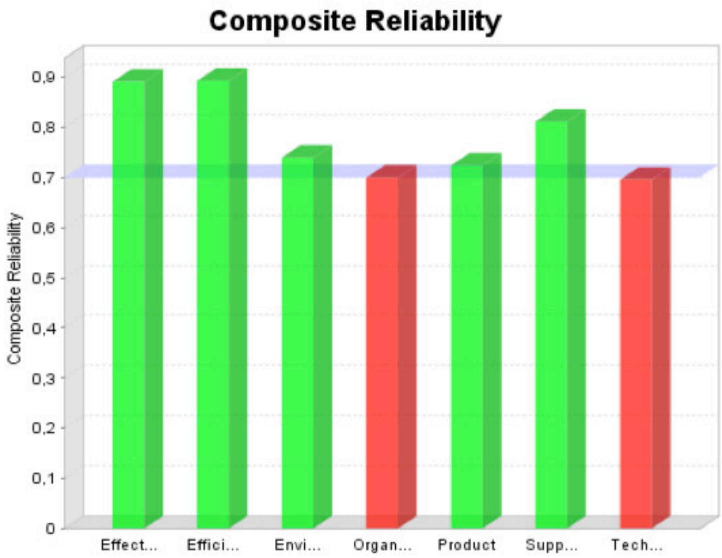
Source: compiled by author. Analysis is based on 110 responses to a questionnaire survey (November 2014 to February 2015) from supply chain members of the German electricity power generation industry.

Figure 9. **Variant 'in general' – f Square**

As stated in figure 9 in the model 'in general', all exogenous variables have an influence on the endogenous variable. A high influence with values of 0.350 or higher can be stated for the influence between the inductive variable Scr and Env as well as Pro. A medium effect can be stated in particular for Pro on Scs and Scy.

Composite reliability, as an alternative measure to Cronbach's Alpha and its assumption that all indicators are equally reliable, assesses the internal consistency reliability by taking into account that indicators have different loadings. The composite reliability measures the sum of a latent variable's factors loading relative to the sum of the factors loading plus error variance. According to literature, for confirmatory research a proposed threshold value is greater than 0.800 or 0.900 whereas the value must not be lower than 0.600.[262]

[262] cf. Nitzl (2010), p. 25 and Urbach and Ahlemann (2010), p. 18-19



	Composite Reliability
Effectivness	0,890
Efficiency	0,892
Environment	0,739
Organization	0,700
Product	0,723
Supply chain readyness	0,811
Technology	0,695

Source: compiled by author. Analysis is based on 110 responses to a questionnaire survey (November 2014 to February 2015) from supply chain members of the German electricity power generation industry.

Figure 10. **Variant 'in general' - composite reliability**

In the model 'in general' and as stated in figure 10, the composite reliability is for the indicator Org 0.700, Env 0.739, Tec 0.695, Pro 0.723, Scr 0.811, Scs 0.890 and Scy 0.892. The values of Org and Tec are below the recommended values, however still exceed the minimum values.

Cronbach's Alpha, as a traditional criterion, measures the degree to which the observable and empirically measurable indicator variable's load is simultaneously with the latent variable increase. A high Cronbach's alpha value assumes, that the scores of all items with one construct have the same range and meaning whereas this criterion tends to severely underestimate the internal consistency reliability of the latent variables in the structural equation model.[263]

In the model 'in general' and as stated in appendix 26, the Cronbach's Alpha is for the indicator Org 0.640, Env 0.583, Tec 0.519, Pro 0.550, Scr 0.722, Scs 0.833 and Scy 0.835.

Overall, the stated latent variables in the structural equation model can be stated as reliable according to the composite reliability and Cronbach's Alpha. Due to stated negative path coefficients of the variables' indicators, the latent variables are not continuously consistent.

[263] cf. Nitzl (2010), p. 25 and Urbach and Ahlemann (2011), p. 18-19

In summary of the structural equation model's assessment for the variant 'in general', it can be stated:

- The exogenous latent variables (Org, Env, Tec and Pro) explain around 50 % of the variance in each endogenous latent variable 'supply chain effectiveness' (Scs) and 'supply chain efficiency' (Scy).
- The inner model path coefficients' sizes and significance suggest that 'product context' (Pro) has the strongest effect on 'supply chain effectiveness' (Scs) followed by 'technological fit' (Tec).

  It also suggested that 'product context' (Pro) has the strongest effect on 'supply chain efficiency' (Scy) followed by a weak effect of 'organizational characteristics' (Org).
- However, the proposed path relationships between Org-Scs, Env-Scs as well as Env-Scy and Tec-Scy are not statically significant.
- Thus the author concludes that 'product context' (Pro) is a moderate substantial predictor of supply chain performance including effectiveness and efficiency.

  The further exogenous latent variables (Org, Env, Tec) do not predict Scs and Scy directly.
- The outer model loadings suggest that Pro3 (product availability) and Pro4 (product life-cycle management) are good indicators of Pro. The indicator Pro5 (product attributes) has a negative impact on Pro.
- The author concludes that 'supply chain readiness' is a moderately substantial and statistically significant inductive variable on the adoption of innovation in inter-organizational supply chains on the base of the inner path coefficients sizes and significance levels.

  The outer model loadings suggest that Scr1 (bargaining power) and Scr5 (inter-organizational dependencies) are good indicators of Scr.
- The endogenous latent variables 'supply chain effectiveness' and 'supply chain efficiency' explain the dependent variable 'supply chain performance' as substantial to good and the construct has a good level of explanatory power.
- Overall it can be stated, that the adoption of innovation in inter-organizational supply chains positively impact the supply chain performance.

Applying structural equation modelling for answer variant 'bar code' and 'RFID'

The author applies for the assessment of the structural model of the answer variant 'bar code' and 'RFID' the same criterions as stated before.

The PLS structural equation model including R Square and its loadings of the answer variant 'bar code' / 'RFID' is stated in appendix 27 / 34. R Square and R Square adjusted are illustrated for the variant 'bar code' in appendix 30 and for the variant 'RFID' in appendix 37. R Square in the model 'bar code' / 'RFID' is for the variable 'organizational characteristics' (Org) 0.258 / 0.235, 'environmental characteristics' (Env) 0.268 / 0.222, 'technological fit' (Tec) 0.184 / 0.099, 'product context' (Pro) 0.372/ 291, 'supply chain effectiveness' (Scs) 0.500 / 0.529 and 'supply chain efficiency' (Scy) 0.556 / 0.606, For both models, the factors 'technology' and 'product' consist each one indicator with a negative loading, which indicates a negative impact on the adoption of supply chain innovation in inter-organizational supply chains, which also explains a lower model fit assessment criterion of R Square.

The criterion R Square adjusted, a modified version of R-Square adjusted for the number of predictors in the model, confirms the stated results of R Square due to only very small differences between both criterions. R Square adjusted, always lower than R Square, is the variant 'bar code' / 'RFID' for Org 0.252 / 0.228, Env 0.261 / 0.215, Tec 0.176 / 0.091, Pro 0.366 / 0.285, Scs 0.481 / 511 and Scy 0.556 / 0.591.

Overall and in accordance with the variant 'in general', the model fit for the variant 'bar code' as well 'RFID' can be stated as substantial to good and the model has a good level of explanatory power. Only the factor 'technology' in the variant 'RFID' is indicated as weak, which can be explained in the following by evaluating the path coefficient of the indicator Tec5 (visible obstacles).

The path coefficients between the models latent variables are also analysed in relation to the algebraic sign, the magnitude and significance and are stated for the model 'bar code' in appendix 28 and 29 and for the model 'RFID' in appendix 35 and 36.

In the both models 'bar code' and 'RFID', the path coefficients between the inductive factor 'supply chain readiness' and the four stated factors of innovation adoption are high and indicate a strong impact. The same impact can be stated for the five indicators of 'supply chain readiness'.

The path coefficients between the independent and the dependent variable indicate a certain impact. In the model 'bar code', the coefficient of the variable 'technology' has a negative impact on supply chain effectiveness and efficiency. The indicator Tec 5 (visible obstacle) has a negative impact on the variable technology. In the model 'RFID', most path coefficients are

marginal lower as the stated levels in literature. The path coefficients for Org-Scy, Pro-Sys and Pro-Scy account for an impact between each latent variable.
The p-values and t-values of the inductive variable ‘supply chain readiness’ and its indicators can be all stated as significant – in the model ‘bar code’ / ‘RFID’ all p-values are between 0 and 0.063 / 0.023 and all t-values are greater than 1.865 / 2.282.
In the model ‘bar code’, the four independent variables Org, Env, Tec and Pro have a lower significant impact on the depended variables Scs and Scy, except the interconnections Env-Scs (p-value 0,315, t-value 1,005).
In the model ‘RFID’, the four independent variables Org, Env, Tec and Pro have a lower significant impact on the depended variables Scs and Scy, except the interconnection Org-Scy (p-value 0,044, t-value 2,018), and the impact of Pro on Scs as well as Sys with p-values of 0 and t-values indicating an error probability of 5 percent.

F Square is also applied by the author to evaluate the effect size in the structural equation model and is stated for the model ‘bar code’ in appendix 31 and for the model ‘RFID’ in appendix 38.
In both model, all exogenous variables have an influence on the endogenous variable. A high influence with values of 0.350 or higher can be stated in the model ‘bar code’ for the influence between the inductive variable Scr and Env as well as Pro and for the influence of Pro on Scs as well as Scy. In the model ‘RFID’, a large effect within the structural model can be stated also for the inductive variable Scr and Pro as well as the relation between the independent and depended variables Pro and Scs and Scy.

Composite reliability and the alternative measure Cronbach’s Alpha for assessing the internal consistency reliability are stated in the model ‘bar code’ in the appendix 32 and 33 and for the model ‘RFID’ in the appendix 39 and 40.
In the model ‘bar code’ / ‘RFID’, the composite reliability is for the indicator Org 0.837 / 0.790, Env 0.675 / 0.673, Tec 0.601 / 0.561, Pro 0.629 / 0.680, Scr 0.766 / 0.795, Scs 0.896 / 0.911 and Scy 0.889 / 0.896. In both models, the values of Env, Tec and Pro are below the recommended values, however sill exceed the minimum values.
In the model ‘bar code’ / RFID, the Cronbach’s Alpha is for the indicator Org 0.765 / 0.715, Env 0.439 / 0.470, Tec 0.388 / 0.370, Pro 0.499 / 0.545, Scr 0.629 / 0.681, Scs 0.842 / 0.867 and Scy 0.830 / 0.841.

Overall, the latent variables Org, Scs and Scy in the structural equation model can be stated as reliable according the composite reliability and Cronbach’s Alpha. Due to stated negative path coefficients of the further variables’ indicator, the latent variables are not continuously consistent and reliable.

For a comparison of the research results between the three structural equation models, the author illustrates a comparison of the R Square of the model's latent variables followed by further analyses of the two enabling technologies for innovation in inter-organizational supply chains.

The comparison of the R Square of the latent variables in the three structural equation models, as illustrated in appendix 41, states only minor differences between the queried information. The exogenous latent variables (Org, Env, Tec and Pro) explain in each model around 50 % of the variance in the endogenous latent variable 'supply chain effectiveness'. The same can be stated for the explanation of the target endogenous variable 'supply chain efficiency' variance.

Before stating a summary of the assessment of the structural equation model for 'bar code' and 'RFID', a further comparison of the quantitative research results of the two enabling technologies for innovation in inter-organizational supply chains is performed.

Comparison of quantitative research results of 'bar code' and 'RFID'

The author carries out a detailed statistical analysis on the aggregated values of the exogenous latent variable for assessing differences between the two enabling technologies investigated by the comparative research design.

Based on the Kolmogorov–Smirnov test as one element of the multivariate analysis of covariance, MANOVA, the empirical data of the two compared variants can be stated as normally distributed. In appendix 42, the nonparametric test values are below the requested values of 0.224 for a population larger the 35 (Org 0.130, Env 0.155, Tec 0.162, Pro 0.192 and Scr 0.156).[264]

Further and stated in appendix 43, the Levene's and Mann–Whitney U test are applied for assessing the equality of variances for the stated exogenous latent variable calculated for both groups – 'bar code' and 'RFID'. As stated in figure 11, the author tests the null hypothesis that the population variances are equal, also called homogeneity of variance or homoscedasticity. Based a on significance level of 0.05, the population variances of each exogenous latent variable for the two groups 'bar code' and 'RFID' can be stated as homoscedasticity.

[264] cf. Backhaus et al. (2011), pp. 183

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The distribution of Envir is the same across categories of BC_RFID.	Independent -Samples Mann-Whitney U Test	,908	Retain the null hypothesis.
2	The distribution of Organization is the same across categories of BC_RFID.	Independent -Samples Mann-Whitney U Test	,982	Retain the null hypothesis.
3	The distribution of Product is the same across categories of BC_RFID.	Independent -Samples Mann-Whitney U Test	,824	Retain the null hypothesis.
4	The distribution of Technology is the same across categories of BC_RFID.	Independent -Samples Mann-Whitney U Test	,601	Retain the null hypothesis.
5	The distribution of SCR is the same across categories of BC_RFID.	Independent -Samples Mann-Whitney U Test	,860	Retain the null hypothesis.

Asymptotic significances are displayed. The significance level is ,05.

Source: compiled by author. Analysis is based on 110 responses to a questionnaire survey (November 2014 to February 2015) from supply chain members of the German electricity power generation industry.

Figure 11. **Comparison 'bar code' and 'RFID' – overview hypotheses test**

In summary of the assessment of the structural equation model for 'bar code' and 'RFID', it can be stated:

- The exogenous latent variables (Org, Env, Tec and Pro) explain around 50 % of the variance in each endogenous latent variable 'supply chain effectiveness' (Scs) and 'supply chain efficiency' (Scy) in both models. The explained variance in Scy is slightly increased.
- The inner model path coefficients' sizes and significance suggest that 'product context' (Pro) has the strongest effect on 'supply chain effectiveness' (Scs).

It also suggested that 'product context' (Pro) has the strongest effect on 'supply chain efficiency' (Scy) followed by a weak effect of 'organizational characteristics' (Org).

In comparison of both models, the variable Tec in the model 'bar code' has a significant negative impact on Scy.

- However, the proposed path relationships between Org-Scs, Tec-Scs, Env-Scs as well as Env-Scy and Tec-Scy are not statically significant.
- Thus the author concludes that 'product context' (Pro) is a moderate substantial predictor of supply chain performance including effectiveness and efficiency.

  The further exogenous latent variables (Org, Env, Tec) do not predict Scs and Scy directly.
- The outer model loadings suggest Pro3 (product availability) and Pro4 (product life-cycle management) are good indicators of Pro. The indicator Pro5 (product attributes) has a negative impact on Pro.

  In both models, the outer model loadings of Tec5 (visible obstacle) indicate a negative impact on the adoption of the adoption of the enabling technology bar code and RFID in inter-organizational supply chains.
- The author concludes that 'supply chain readiness' is a moderately substantial and statistically significant inductive variable on the adoption of innovation in inter-organizational supply chains on the base of the inner path coefficients sizes and significance levels.

  The outer model loadings in both models suggest in accordance to the model 'in general' suggest that Scr1 (bargaining power) and Scr5 (inter-organizational dependencies) are good indicators of Scr.
- Based on the homoscedasticity of the population variances of each exogenous latent variable for the two groups 'bar code' and 'RFID', a reliable and valid difference of the two enabling technologies for the adoption of innovation in inter-organizational supply chains cannot be stated.
- In accordance to the results in the model 'in general', the endogenous latent variables 'supply chain effectiveness' and 'supply chain efficiency' explain the dependent variable 'supply chain performance' also as substantial to good and the construct has a good level of explanatory power.
- Overall it can be stated, that the adoption of innovation in inter-organizational supply chains positively impact the supply chain performance.

General questions do not imply deviating research results

The general questions are analysed by applying mainly descriptive statistics.

Within question 33 (GQ1) regarding the company's core competency, 52,7 percent of the respondents state the company's core competency as the operation of an existing power plant (electricity production), 47,3 percent of the respondents state a different core competency. Nine respondents did not answer this question. In account with the qualitative interviews, a different position regarding managerial impact factor for supply chain innovation cannot be stated. Therefore, the focus of the research might not only be limited to the stated basic population and the German industry of electricity power generation.

Question 34 (GQ2) regarding the respondent's position respectively the management level within the company is represented by a histogram in appendix 44. Three respondents stated the level of a supply chain manager / purchasing manager / operations manager as a manager, 10 as a supervisor, 23 as a worker. One respondent did not specify the level of management and 52 respondents did not answer the question.

Question 35 (GQ3) regarding the respondent's years in position respectively the time-period within the management level within the company is represented by in a histogram in appendix 45. A time period of 0-1 years indicated 13 respondents, 2-5 years 10 respondents, 6-10 years 7 respondents, 11-15 year 15 respondents, 16 and more year 13 respondents and 52 respondents did not answer.

Question 36 (GQ4) regarding the respondent's years in industry respectively the time-period within industry is represented by a histogram in appendix 46. A time period of 0-1 years indicated 8 respondents, 2-5 years 6 respondents, 6-10 years 7 respondents, 11-15 year 5 respondents, 16 and more year 32 respondents and 52 respondents did not answer.

Based on further initial analyses and in accordance to the qualitative research part, significant differences of level of management, years within the management level as well as years within the industry regarding the managerial factors for supply chain innovations and its impact on supply chain performance cannot be stated.

Question 40 (GQ7), respondent is a supply chain partner of the electricity power generation industry, is confirmed due the stated research design by all respondent from the fair trade.

Question 41 (GQ8), company's section of branch of trade, is answered by only 58 participants and the results are represented in a histogram in appendix 47. 48 respondents indicate manufacturing (Section C) as the company's section of branch of trade.

3.3. Reflection and interpretation of empirical data based research results

Today's rising importance of supply chain management, caused by ongoing trends of globalization, increasing market competition as well as uncertainty of marketplaces, requires an innovation and adaption processes to meet the future challenges. Innovation in supply chain management with regard to further supply chain integration and collaboration among the overall supply chain are also key elements for transforming actual supply chain management concepts, such as the Internet of Things and 'Industrie 4.0' concept, into reality of everyday business operations.

The author applies in this thesis the term 'supply chain integration' (SCI) as a strategic collaboration of supply chain partners who collaboratively manage intra- and inter-organizational processes in order to achieve effective and efficient flows of products and services, information, money and decisions.

The research results, based on empirical data from both research methods, are reflected with pervious research studies. The interpretation of the research results is outlined for each managerial impact factor of innovation in inter-organizational supply chain integration and its impact on the stated variables of supply chain performance.

Initiator 'supply chain readiness'

'Supply chain readiness' is clearly derived from empirical data as an inductive variable for adoption of innovation in inter-organizational supply chains. All five indicators – 'bargaining power', 'initiator', 'trust', 'partner readiness' and 'inter-organizational dependencies' – are identified as relevant indicators for 'supply chain readiness'.

The two most substantial indicators are 'bargaining power' and 'trust.' Trust is one key element for further supply chain integration and collaboration between supply chain members. Previous researches indicate the importance of social and organizational issues in establishing collaboration between supply chain partners.[265] Quetti et al. (2012) also identify trust among trading partners, build on top of a solid relationship and a recognized competence, as one contributing success factor of the adoption process.[266]

Bargaining power, often referred in the interviews with experts as a strong sub-factors, is also found significant in previous researches in particular of technological innovations.[267]

The research result of a positive impact of the sub-factors 'inter-organizational dependencies' and as well as 'partner readiness' is consistent with previous research studies such as Cheng et al. (2014), who suggest "that an institutional orientation among supply chain members can

[265] cf. Kosanke (2005), pp. 6
[266] cf. Quetti (2012), p. 327
[267] cf. Iacovou et al. (1995), p. 476 and Quetti et al. (2012), p. 327

ensure the advantages of inter-organizational collaboration and in turn enhance inter-organizational innovation performance".[268]

Sharma et al. (2007) identify supply chain partner power within the semi-structured interviews regarding strategic perspectives in the adoption of RFID integration.[269]

Factor 'product context'

As one novel aspect within the research model stated in this thesis, the managerial impact factor 'product context' for the adoption of innovation in inter-organizational supply chains is identified as substantial and significant. Only few previous researchers incorporate the aspect 'product attributes' as an explicit variable in the research model.

Wong et al. (2011) identify operating characteristics of firms in terms of product complexity and durability to improve cost and customer orientated operational performance in supply chain management. In this study operation characteristics cover product type and product complexity.[270]

Based on the empirical data in this research, the author highlights the aspects 'product availability' as well as 'product lift-cycle management', both relevant for maintenance, repair and overhaul processes in capital-intensive industries, as improving sub-factors for the adoption of innovation in inter-organizational supply chains.

Factor 'organizational characteristics'

The managerial impact factor 'organizational characteristics' is a well-applied factor for innovation in previous supply management and electronic business researches. The author identifies 'organizational characteristics' as a managerial impact factor for innovation, although with a weak impact. The indicators 'financial resources' and 'top management' have higher impact compared to 'organizational size'.

Support by top management is identified by the empirical data of both research methods as an essential and fundamental element for innovation. This finding is consistent with other research findings, such as the research by Premkumar and Roberts (1999) in rural small businesses, which identifies top management's commitment to the innovation as essential to get adequate resources and support for implementing the innovation. In the research by Quetti et al. (2012), all interview partners indicate top management support as fundamental.[271]

'Financial resources' and 'company size' are well-researched elements for the adoption innovation, whereas 'financial resource' is stated as a more evidently factor. The indicator 'company size' cannot be supported in this thesis as an influencing sub-factor for innovation

[268] cf. Cheng (2014), p. 181, Premkumar and Roberts (1999), p. 481-482, Falke (2013), p. 2
[269] cf. Sharma et al. (2007), p. 3763
[270] cf. Wong et al. (2011), p. 189-190
[271] cf. Premkumar and Roberts (1999), p. 480 and Quetti et al. (2012), p. 326

in inter-organizational supply chains. Previous research findings are indeed inconsistent about the role of company size. The interviewee partners in this thesis highlight the necessity of financial resources and top management support for adopting innovation in supply chain management and correlate this with the size of a single supply chain member, potentially in the role of an initiator, or a supply chain network. In other findings such as stated by Quetti et al. (2012), company size is also suggested as a proxy to larger internal resources committable to an adoption of innovation. Wamba (2012) conclude, that the company size does not matter when adopting and using technology. Chang et al. (2008) exclude organizational size from the main factors in (RFID technology) adoption. Further research finding indicate company size as a relevant determinant.[272] The author of this thesis considers 'company size' as a correlated indicator to 'financial resources' for the adoption of innovation in inter-organizational supply chains.

The factors 'environmental characteristics' and 'technological fit' are excluded by the thesis' quantitative research part from the main managerial impact factors for innovation in inter-organizational supply chains. However, the interviews with experts add qualitative findings to the influence of these factors in the decision making and adoption process.

Factor 'environmental characteristics'

Based on the results of the quantitative research method, the strongest sub-factors for the managerial impact factor 'environmental characteristics' are 'competitive pressure' followed by 'innovation maturity' and 'industry environment'. The sub factor 'uncertainty of environment', predicted by the author as relevant in particular in the actual phase of the German energy transition, is not identified as relevant in both applied research methods in this thesis.

Competitive pressure from supply chain partners is discussed before and examples are given in retail business. Chang et al. (2008) highlight the pressure from transaction partner. Scupola (2003) confirms the pressure from competition and from trading partner as an important factor for innovation adoption.[273]

Factor 'technological fit'

The factor 'technological fit', covering the indicators 'complexity', 'compatibility' and 'visible obstacle', is identified in the structural equation model as having a weak impact on supply chain effectiveness. In the interviews with experts, all indicators are central aspects of the knowledge and experience exchange.

[272] cf. Chang et al. (2008), p. 212-213, Premkumar and Roberts (1999), p. 480, Quetti et al. (2012), p. 326-327, and Wamba (2012), p. 63

[273] cf. Scupola (2003), p. 67, Premkumar and Roberts (1999), p. 481, and Chang et al. (2008), p. 212

Most innovations imply change consequences on the business organization and processes as well as (enabling) technologies. In technological and electronic business research and its journals, the applied sub-factors are researched for individual enabling technologies in a broader or narrowed perspective. Within this thesis, industrial as well as research organizations and business consultancies state the need for investigating and analysing the actual processes across the entire supply chain as a base for re-designing the supply chain. Interviewees agree to the integral view of systems theory and the impact of small changes in the whole system. Davenport (1993) states that even constraints of a technological innovation need to be explicitly factored into process re-design.[274]

The research by Quetti et al. (2008), applying qualitative research method to the RFID technology adoption in the case of the Italian silk industry, respondents identify the complexity of RFID technology as low and compatibility is found capable of effecting RFID technology adoption.[275]

However, the interview partners in this thesis clearly demand a business process redesign as elementary to generate further benefits from implementing RFID technology as well as within any further supply chain innovation. This finding can be correlated with the findings of Leung et al. (2007) that an application of RFID tags as a high-tech version of bar codes is not a very economically usage due to the price premium - moreover, significant changes in business processes need to be made.[276] It is necessary to derive further business value from its unique technical characteristics by redesigning underlying material flow and information processes.

The sub-factor 'visible obstacle', potentially perceived by the decision maker for hindering a successful implementation of supply chain innovation, is mainly discussed and described of having a negative impact within the decision-making process regarding RFID technology. One major aspect in the interviews with experts is the security aspect of an Auto-ID technology implementation in intra-organizational supply chains.[277] However, within supply chains only between business customers, such as the electricity power generation industry, security aspects are stated as of inferior standing.

Subsumption of compared enabling technologies for inter-organizational supply chain innovation

The qualitative and quantitative research methods clearly indicate results regarding the compared enabling technologies for the adoption of innovation in inter-organizational supply chains – bar code and RFID technology. Literature research as well as the interviews with

[274] cf Davenport (1993), p. 66, Yücesan (2007), pp. 130, and Chang et al. (2008), p. 213-214
[275] cf. Quetti et al. (2012), p. 326-327
[276] cf. Leung et al (2007), p. 68
[277] cf. Ngai et al. (2008), p. 518, Zhu et al. (2012), p. 163, and Mostaghel et al. (2012), p. 244

experts indicates potential differences of its adoption and impact on supply chain performance.

One challenge for future practical and research initiatives is carving out collaborative advantages of implementing an Auto-ID technology in intra-organizational supply chains in the electricity power generation as well as any other industry.[278] In contrast to the stated competitive advantages, for example as defined by Michael E. Porter, supply chain activates need to be evaluated according to the stated systems theory and its prediction that changes or actions taken in one subsystem impact the other subsystems as well as the whole system.[279] The implementation of an Auto-ID technology at one stage of the ultimate supply chain might influence activities of all supply chain members. Downstream supply chain members - supply chain members that receive a tagged or bar coded product - are able to take advantage of this product characteristic and upstream supply chain members might be pushed to tag or bar code a product at this upstream productions step.

This thesis clearly indicates the lack of carving out collaborative advantages. International organizations that develop and maintain standards for supply and demand chains across multiple sectors bring together supply chain members to force supply chain integration by adopting Auto-ID technologies and showing collaborative advantages for all supply chain members. Industrial, business and trade associations define policy documents to start and promote such initiates. However, the author calls on every supply chain member to discuss collaborative advantages by implementing adequate Auto-ID technology in the intra-organizational supply chain with its upstream and downstream supply chain partners. Supply chain integration, e.g. in terms of flow of material and information, has to come from the supply chain members themselves in order to create seamlessly coordinated supply chains. Based on the resulting innovations, the overall supply chain and its member will profit from the created supply chain collaboration.

The applied systems theory in this thesis suggests that changes in one aspect of a system will result in changes in other parts of the system. The implementation of an Auto-ID technology is such a change in the system supply chain. The author deducts two relevant enabling technologies for innovation in inter-organizational supply chain.

Cooper and Tracey (2005) summarize one overall limitation for adopting an innovation by stating, that “each supply chain must be customized to fit its unique circumstances, and selecting and effectively using the appropriate information technology”.[280] This indicates, that

[278] cf. Chen and Paulraj (2004), p. 121 and Ahuja (2000), pp. 335
[279] cf. Johnson et al. (1963), p. 52
[280] Cooper and Tracey (2005), p. 251

an enabling technology needs to be chosen for every single supply chain. Different approaches with suppliers and customers might be adequate, although not a perfect condition. With reference to the compared enabling technologies in this thesis, Keller (2011) states, that after comparing characteristics of RFID technology against object identification using bar codes, some major advantages for both technologies can be identified.[281]

As explained in the previous chapters and as recent publications indicate, the reality of RFID technology adoption in almost all industries is far behind earlier expectations.[282] The development of the Internet of Things has been also slower than expected caused mainly by the missing profitability for each individual stakeholder.[283] However, even today's existing RIFD technology applications can be considered as a progress in the development of the Intranet or even Extranet of Things to a fully integration of virtual and real things within the Internet of Things and the Future Internet of Things and People.[284]

Today, several technological constraints limit a fully reliable and productive use of the Internet of Things concept and its underlying technologies, such as RFID technology.

One interviewee clearly expressed his expectation that an accuracy of 97 percent automatic gather dated is not enough. Next to unexpected read events due to the absorption and reflection of radio waves, Soylemezoglu et al. (2006) experienced read rates on RFID antennas vary between 70 and 80 percent depending on product character and they stated clearly that if the read-rate problem cannot be solved, the ultimate goal of RFID technology, achieving 100 % visibility in supply chain applications, can not be realized. Keller (2011) acknowledged this position. He stated that RFID technology is not completely error free given that the basic principles of radio frequency waves and their limitations have a direct influence upon the readability of RFID tags.[285]

The major economical aspect limiting the fully potential of increasing supply chain efficiency are in particular the cost of RFID technology. Interviewees highlighted the impact of cost of tags on supply chain efficiency. During the early phase of the spread of RFID technology, the cost of RFID tags were expected to decrease significantly - starting form 25 Cent US Dollar per passive tag in 2004 with an annually decrease in cost of 30 or 20 percent to 5 or 10 Cent US Dollar per passive tag in 2010.[286] The interviewees in this thesis perceive the benefits of reaching the goal of cost of 5 cent as not sufficient for implementing this enabling technology

[281] cf. Keller (2011), p. 2 and Chan et al. (2012), p. 804
[282] cf. Yao et al. (2012), p. 3507
[283] cf. Uckelmann and Scholz-Reiter (2011b), p. 229
[284] cf. Uckelmann et al. (2011), p. 3. Please see also appendix 4.
[285] cf. Jones and Chung (2008), p. 26, Buyurgan (2010), 453, Soylemezoglu et al. (2006), p. 134-135, and Keller (2011), p. 6
[286] cf. Becker (2004), p. 12, Banks et al. (2007), p. 22-23, and Leung et al. (2007), p. 249

in innovation project in inter-organizational supply chains. Matta and Ferger (2012) find that "industry members of the logistic and transportation sector […] demonstrated a significantly negative perception of cost vs. benefit for this new [RFID] technology".[287]

Overall, the recent evolution of RFID technology is a further advancement to the idealized theories of supply chain management - the availability of an item in the correct quantity and condition at the correct time and place. Beyond that, the automatic identification of any object anywhere and therefore the so-called Internet of Things seems not even to be possible with today's technology.[288]

Banks et al. (2007) state, that bar coding in warehouse and distribution systems is unlikely to be totally replaced by RFID technology overnight. They also indicate, that receiving, storing, picking and shipping process will become more efficient and effective with RFID technology.[289]

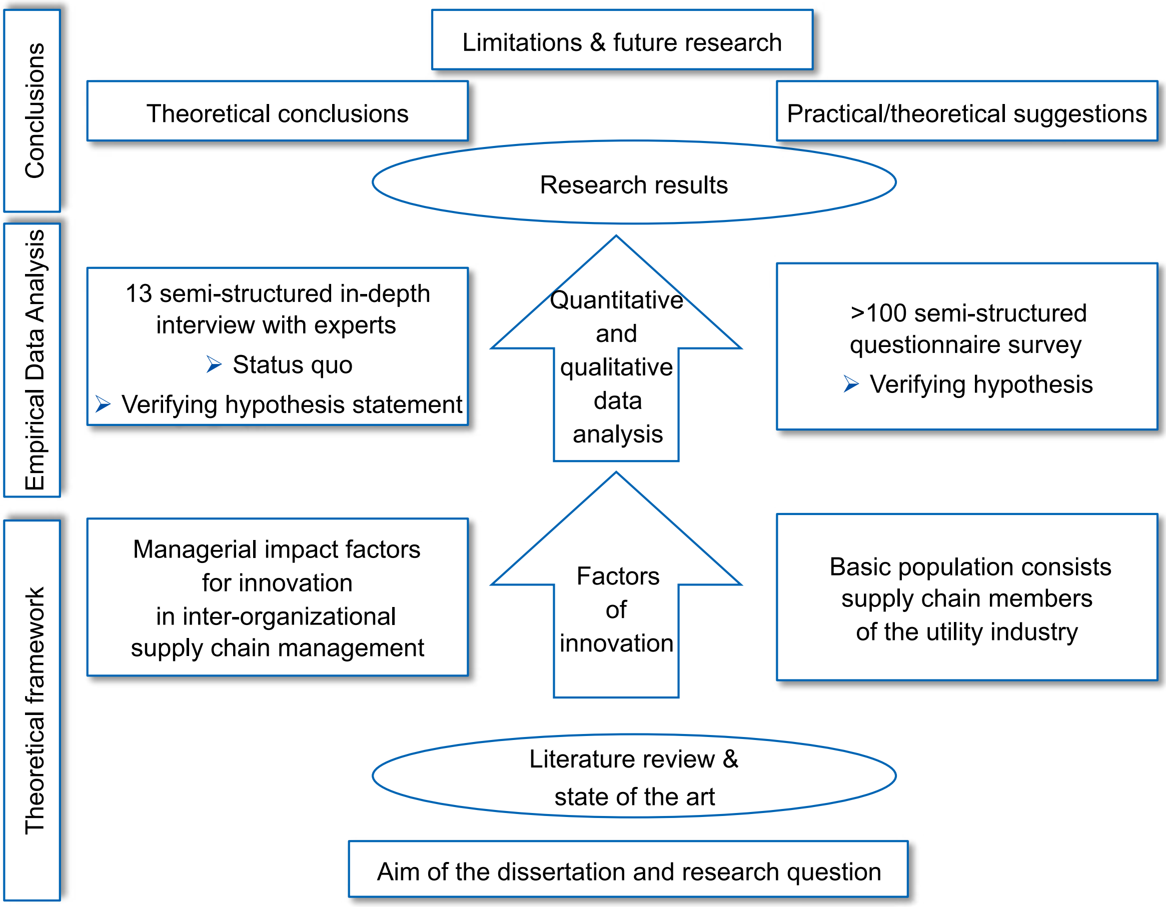
In summary and based on the homoscedasticity of the population variances of each exogenous latent variable for the two groups 'bar code' and 'RFID', the author cannot state a reliable and valid difference of the two enabling technologies for the adoption of innovation in inter-organizational supply chain. However, the stated and reflected findings regarding enabling technologies within innovations in inter-organizational supply chain should stimulate and promote future supply chain integration and collaboration among the ultimate supply chain.

[287] Matta and Feger (2012), p. 4734
[288] cf. Pflaum and Hupp (2007), p. 107
[289] cf. Banks et al. (2007), p. 370. See also Zelbst and Sower (2012), p. 46, Vance et al. (2012), p. 65, Zipkin (2007), p. 70, and Nemeth (2006), p. 244.

Conclusions and Suggestions

The conclusions and suggestions are stated in the following as a result of the executed research process in this thesis.

The research process, as illustrated in figure 12, as well as the conclusions and suggestions are derived from the theoretical framework in this thesis, the analysis of the empirically gathered data, and the formulation of the research results on the basis of the applied qualitative and quantitative research methods.



Source: compiled by author

Figure 12. **Overview of thesis' research process**

In order to answer the research question, this thesis improves the in-depths knowledge of managerial impact factors for innovations in inter-organizational supply chains. As one main result of the research process, the author concludes the following statements regarding the theses for defence:

- The adoption of innovation in inter-organizational supply chains increases the supply chain performance. -> partly substantiated

- Supply chain performance is constructed of supply chain effectiveness and supply chain efficiency. -> substantiated
- Enabling technologies for innovation, bar code and RFID technology, support supply chain performance in inter-organizational supply chains. -> rejected

The following propositions are addressed for examining the main theses for defence and the overall research question and are answered as following:

- Proposition 1: The factors 'organizational characteristics', 'environment characteristics', 'technological fit' and 'product context' positively impact the supply chain effectiveness. –> partly substantiated
- Proposition 2: The factors 'organizational characteristics', 'environment characteristics', 'technological fit' and 'product context' positively impact the supply chain efficiency. –> partly substantiated
- Proposition 3: The factor 'supply chain readiness' supports the adoption of innovation in inter-organizational supply chains. –> substantiated

The research model is applied in a comparative research design for three variations of response. Next to a general adoption of the research model, it is also adopted to two relevant enabling technologies for innovation in inter-organizational supply chains in order to accomplish concepts of future supply chain management.

- Proposition 4: The increase of supply chain effectiveness by applying bar code technology as an enabling technology within supply chain innovation adoption is higher compared with RFID technology. –> rejected
- Proposition 5: The increase of supply chain efficiency by applying RFID technology as an enabling technology within supply chain innovation adoption is higher compared with bar code technology. –> rejected

Conclusions

The author deduces the following key conclusions out of this empirical research:

1. The stated recent research identifies the need for a substantial advancement of process integration with external supply chain partners. The theory of future supply chain management is actually defined by the Internet of Things concept and terms like cyber-physical systems, 'Smart Factory' and the German research approach of 'Industrie 4.0', which is called 'Industrial Internet' in the United States of America. Supply chain innovation is needed to implement these concepts of future supply chain management in inter-organizational settings.
2. Supply chain innovation is identified as necessary for meeting the stated predatory market competition in the German electricity power generation industry.

Currently and as stated before, most supply chain transactions in the German electricity power generation industry are performed with media discontinuity. The physical flow of material is still performed paper-based in the form of an attached delivery note. A potential 'to be and integrated' supply chain process covers the principles of the Internet of Things concept with a combination of a real object and its virtual presence, by an integrated data warehouse and exchange of information. The physical movement of a material lot size tagged by, for example, RFID technology is combined with real-time identification of the material's location and real-time updated movement data. Such an integrated supply chain offers potential for reducing the cost of operation of outbound and receiving processes for all supply chain partners.

3. A valid and reliable scale of measurement in the form of an interview guide and a questionnaire for the novel construct of managerial impact factors for innovation and their impact on supply chain performance covering effectiveness and efficiency within inter-organizational supply chains is stated in this thesis.
4. The derived construct of antecedents of supply chain innovation in inter-organizational supply chains is identified as a tool for business managers in their decision-making process in order to adopt and implement innovation for reaching concepts of future supply chain management.
5. The research results highlight in particular the factors 'product context' and 'technological fit' for increasing effectiveness within the adoption of innovation in inter-organizational supply chains.

   The structural equation model and underlying multivariate statistical analyses clearly indicate a positive impact of the latent variable 'product context' followed by 'technological fit' on supply chain effectiveness. However, the further managerial impact factors 'organizational characteristics' and 'environmental characteristics' do not predict supply chain effectiveness directly.
6. For increasing inter-organizational supply chain efficiency, the research results identify the determinant 'product context' as most relevant within the decision-making process for adopting and implementing supply chain innovation.

   The results of the empirical data analyses in this research clearly state the positive impact of the latent variable 'product context' on supply chain efficiency. However, the further managerial impact factors 'organizational characteristics', 'environmental characteristics' and 'technological fit' do not predict supply chain efficiency directly.

7. The research results indicate that the readiness of the underlying supply chain and its supply chain partners is a major factor within the decision-making process for adopting and implementing supply chain innovation in inter-organizational supply chains.

   ‘Supply chain readiness’ is a moderately substantially and statistically significant inductive variable on the adoption of innovation in inter-organizational supply chains. In particular, the indicators ‘bargaining power’ and the presence of existing ‘inter-organizational dependencies’ positively influence the adoption of innovations.

8. The research and its results assess the adoption of the two enabling technologies for innovation in the underlying inter-organizational supply chain.

   Literature review as well as the qualitative research method interviews with experts indicate a potentially higher increase of supply chain effectiveness of bar code compared to RFID technology. Overall and in accordance to the research results of the quantitative research method including the homoscedasticity of the population variances for the two groups ‘bar code’ and ‘RFID’, a reliable and valid difference of the two enabling technologies cannot be stated in this research.

9. The bar code technology, in particular the two-dimensional and QR codes, meets the requirements of future industrial concepts. Today's industrial and economic-political theory, such as the ‘Industrie 4.0’ concept, will base on various Auto-ID technologies. Due to the described necessity of applying the proper Auto-ID technology for each supply chain application, bar code as well as RFID technology will be part of these concepts. Interviewees state the limitations of bar codes within the ‘Industrie 4.0’ concept, which ultimately contains smart supply chain objects with the capacity to ‘think’.

Suggestions

The stated and interpreted research results regarding the proposed construct of managerial impact factors for adoption of innovations in inter-organizational supply chains contain both managerial and theoretical implications for different groups of addressees.

Practical implications to supply chain managers are stated by the author as following:

1. Supply chain managers are requested to promote and implement supply chain integration and collaboration along the ultimate supply chain. The researched managerial impact factors, including sub-factors, might assist supply chain mangers as a tool in their decision-making process for selecting the appropriate supply chain innovation.
2. Business organizations are asked to apply the derived construct of antecedents of supply chain innovation in inter-organizational supply chains within their decision-making process in order to adopt and implement innovation for reaching concepts of future supply chain management.

   Business managers are asked in particular to consider the factors 'product context' and 'technological fit' for increasing effectiveness within the adoption of innovation in inter-organizational supply chains. For increasing inter-organizational supply chain efficiency, business organizations might take into account the determinant 'product context' in the decision-making process for adopting and implementing supply chain innovation.

   Business organizations are requested to focus on the readiness of the underlying supply chain and its supply chain partners within the decision-making process for adopting and implementing supply chain innovation in inter-organizational supply chains.
3. Financially strong companies, such as interconnected companies or large regional utilities, are asked to act as initiators for supply chain innovation.
4. Supply chain members with the adequate financial resources are suggested to push supply chain innovation in cooperation with other supply chain members. This thesis clearly indicates the relevance of the indicator 'financial resources' for the development and implementation of innovations. This suggestion does not imply the utilization of different bargaining power among supply chain members and the obligation of financially weak supply chain members to implement all claims. Furthermore, financially strong companies are asked to push joined innovation initiatives along the ultimate supply chain.
5. Supply chain managers need to re-think and potentially re-design inter-organizational supply chain processes during the development of innovations.
6. Supply chain members are also requested to re-design processes within the adoption of innovations in inter-organizational supply chains. The need for a re-design of processes in

innovation projects was clearly expressed and demanded in the interviews with experts. In line with the principles of systems theory and as illustrated in appendix 4, supply chain management requires careful planning and close coordination of three types of flows – material, information and financial – by optimizing the three key building blocks - process, organizational structure and enabling technologies. All of these elements need to be re-thought and optimized by all members of the supply chain.

7. Supply chain partners with high bargaining power might promote innovation with members of their extended or even ultimate supply chain with the goal of establishing a win-win solution.
8. Supply chain members have to establish a certain level of trust in their relationship. Strategic partnerships, optionally framed by a signed long-term agreement, are the basis for further supply chain integration and the adoption on innovation in inter-organizational supply chains.
9. Managers of the supply chain and further business processes are requested to cooperate in order to force vertical, inter-organizational supply chain integration.
10. Supply chain managers are asked to define common goals within each supply chain network. In industries namely the food and fast-moving consumables industry, various studies and industrial networks made efforts to implement (technological) innovations in inter-organizational networks focusing primarily on cost reduction. The goals of the German automotive industry and its networks could function as a role model regarding the goals of further supply chain integration focusing on complex product, process and information technology innovations and a secondary objective of cost reduction along the ultimate supply chain.
11. Engineers responsible for maintenance, repair and overhaul actions are requested to be aware and actively demand supply chain innovation for minimizing overhaul cost and downtime of electricity power generation units.

Practical implications to other industries are stated by the author as following:

12. Further capital-intensive industries with a large of portion of maintenance and overhaul activities might also apply the deducted results in their business environment.

    In the previous chapters, the author of this thesis clearly outlines the specific characteristics of the German and European electricity industry and its actual need for innovation in inter-organizational supply chains in order to meet the industry's predatory competition including the cost pressure on each electricity power unit. The stated findings might also be transferred to comparable industries such as the chemical industries with capital-intensive production facilities and high amount of maintenance.

13. Medium and small sized companies are also requested to be aware of innovative potentials and managerial impact factor in their supply chain to benefit as early as possible from advantages of supply chain integration and network benefits as well as the innovation cost advantages in particular in international competition in order to meet the German industrial concept of 'Industrie 4.0'.

Practical implications to researchers and organizations are stated by the author as following:

14. Public and private research institutions and organizations, such as GS1 and EECC, are requested to support and stimulate the further implementation of relevant enabling technologies, such as relevant Auto-ID technologies in supply chain management - mainly in projects within each industry sector and compliant supply chain partners. Public institutions, such as the federal states, the federal government and ministries and the European Union, are asked to fund these cooperation projects between research initiations and industry.
15. Public and business organizations are suggested to push initiatives to further standardize regulations and technological aspects in order to minimize visible obstacles for an (technological) innovation adoption by business organizations.
16. Future researchers are asked to investigate further factors of supply chain innovation, which might impact the implementation of innovations and the overall supply chain performance.
17. Actual and future research initiatives as well as promoting associations and organizations of the 'Industrie 4.0' concept are requested to recognize and push a multi-stage approach for reaching the goals of the concept including the inclusion of different enabling technologies such as globally proven bar code technology.

Practical implications for supporting the two researched enabling technologies are stated by the author as following:

18. Supply chain managers are asked to properly select and critically access an appropriate enabling technology for adopting a supply chain innovation considering the unique circumstances of the supply chain. A further integration of Auto-ID technology supported items in the supply chain will combine the real and virtual world in the idea of the Internet of Things. Further development of RFID and sensor technology might facilitate designing

and implementing cyber-physical systems within the future ‘Smart Factory’. A multi-stage innovation implementation indicates a possible solution for reaching this solution.

19. Supply chain mangers are requested to be aware and even carve out additional benefits of the implementation of Auto-ID technologies in the company’s supply chains. A further virtualization of items in the supply chain offers potential for further optimization of the supply / value chains by using real-time information.
20. Supply chain mangers might consider enabling technologies for supply chain innovation in relation to an enhanced opportunity to realize environmental protection. With an increasing society interest in environmental protection, additional real time information might assist companies in a further development of green logistics, including carbon dioxide reduction along the ultimate supply chain.
21. Business leaders might consider the ability to return production capacities to industrialized nations. By an ongoing aggregation of information along the supply chain and its members, the elimination of the classical division of work between producers, consumers and service providers might be a sustainable change in today's economical world. Today outsourced production capacities to low-wage countries might be returned to headquarters and production locations in industrialized nations.

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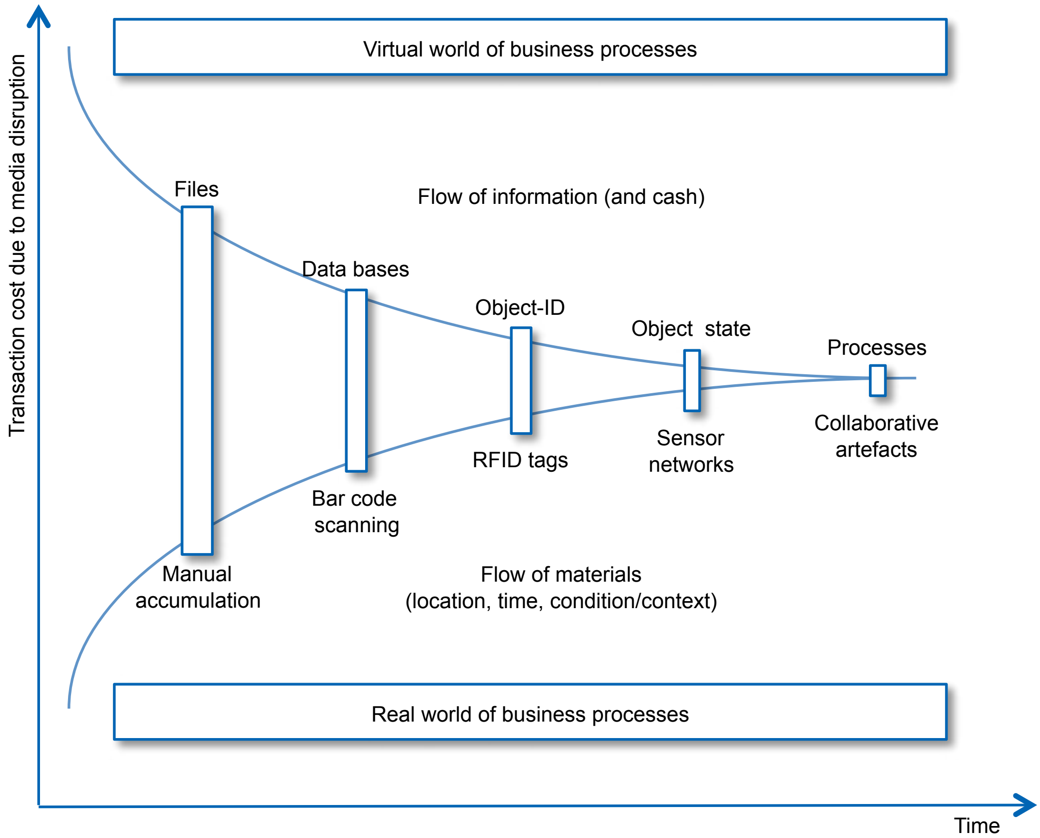
Appendixes

Page



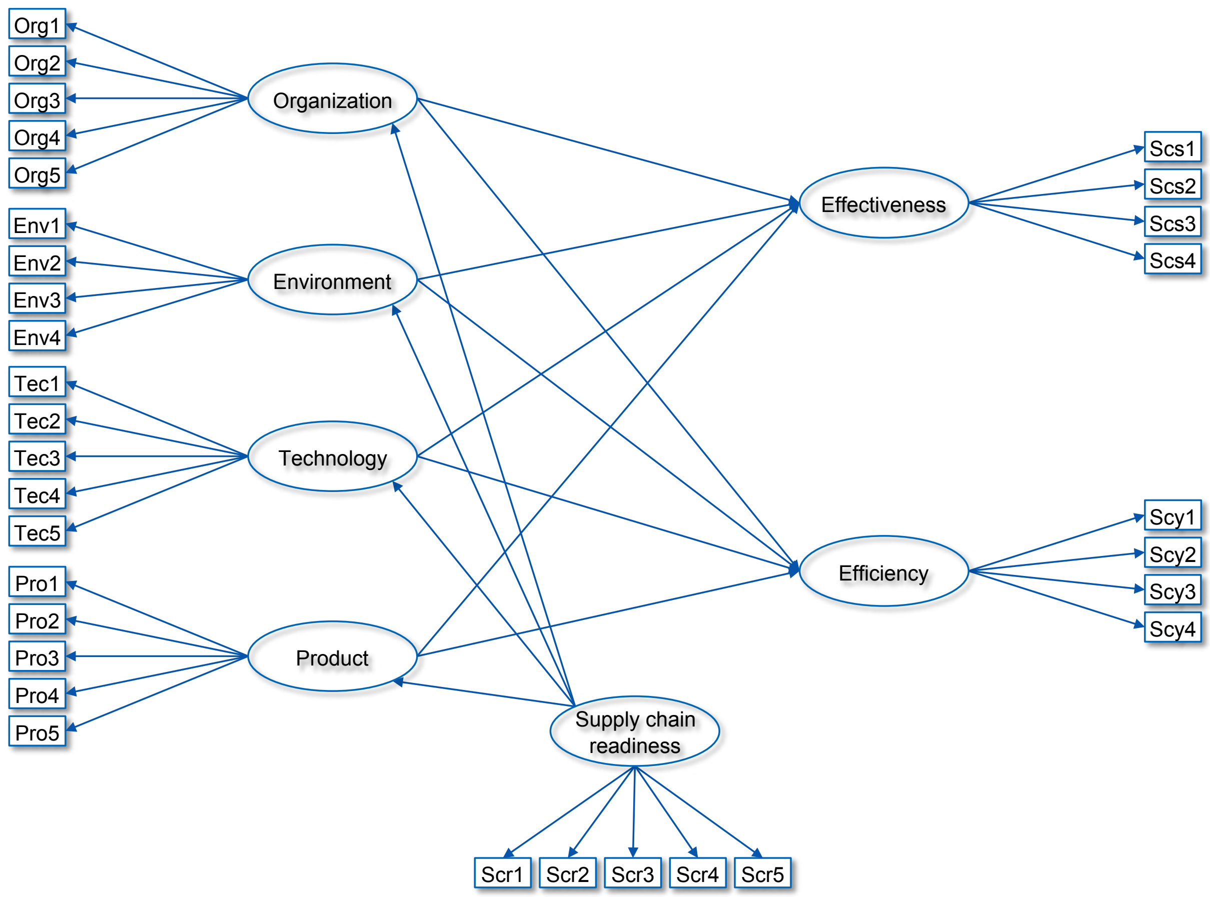
Source: derived by author from Gillert and Hansen (2007), p. 7 and Decker et al. (2008), p. 156

Appendix 1. **Evolution from supply chain management to the Internet of Things (in 2015)**

Aim of the dissertation and research question Question: What is the author's motivation and goals of this thesis? Content: Actuality and novelty of research topic Research question and hypothesis Approbation of results of research Result: Research question and main hypothesis outlined for research	Introduction
Theoretical framework Question: What are the impact factors for further supply chain integration? Content: Actual challenges of today's supply chain management Supply chain integration and its further visions Factors for innovation in inter-organisational supply chains Result: Set of potential factors for innovation in supply chain integration	Chapter 1
Conceptual framework Question: How may enabling technologies support for innovation? Content: Role of enabling technologies within supply chain innovation Evaluation of relevant Auto-ID technologies for supply chains Need for innovation in electricity power generation industry Result: Necessity of innovation for reaching actual supply chain visions	Chapter 2
Research method and research design Question: How can innovation factors comparatively be researched? Content: Sequential triangulation research approach Expert interviews for in-depth research of factors Semi-structured questionnaire with comparative research style Result: Multimethod research design for innovation factors	Chapter 3
Results of research Question: What is the indication of research results for innovation factors? Content: Development and statement of overall research results Interpretation of research results from both methods Limitations and suggestions for further research Results: Implications for innovation in supply chain integration	Chapter 3
Conclusion and suggestions Question: What is the indication of research results for innovation factors? Content: Theoretical conclusions of research results Suggestions for practical implications Results: Implications for innovation in supply chain integration	Conclusion and Suggestion

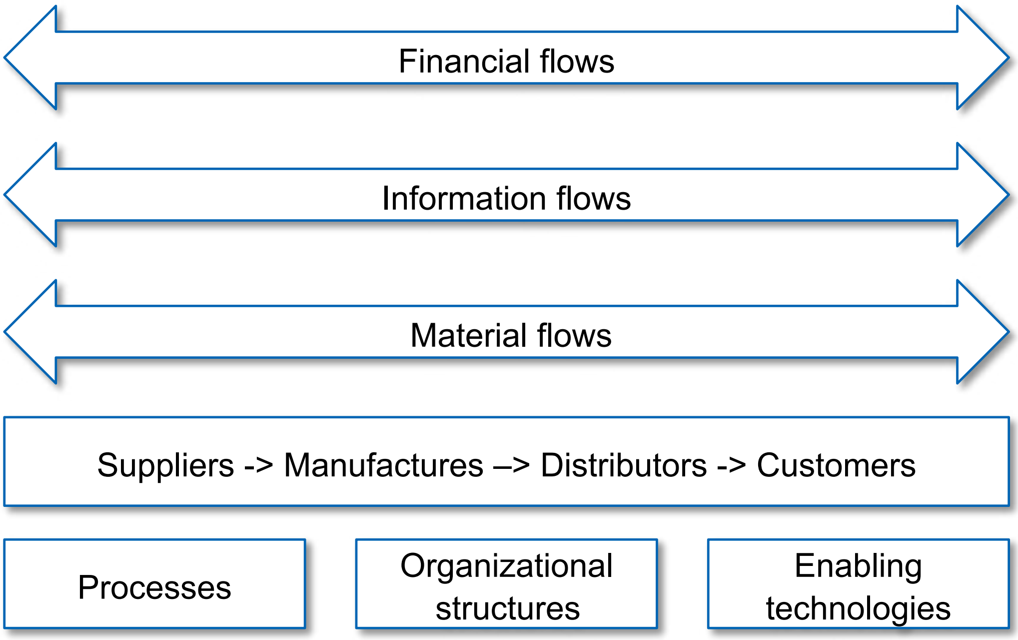
Source: compiled by author

Appendix 2. **Structure of the thesis**



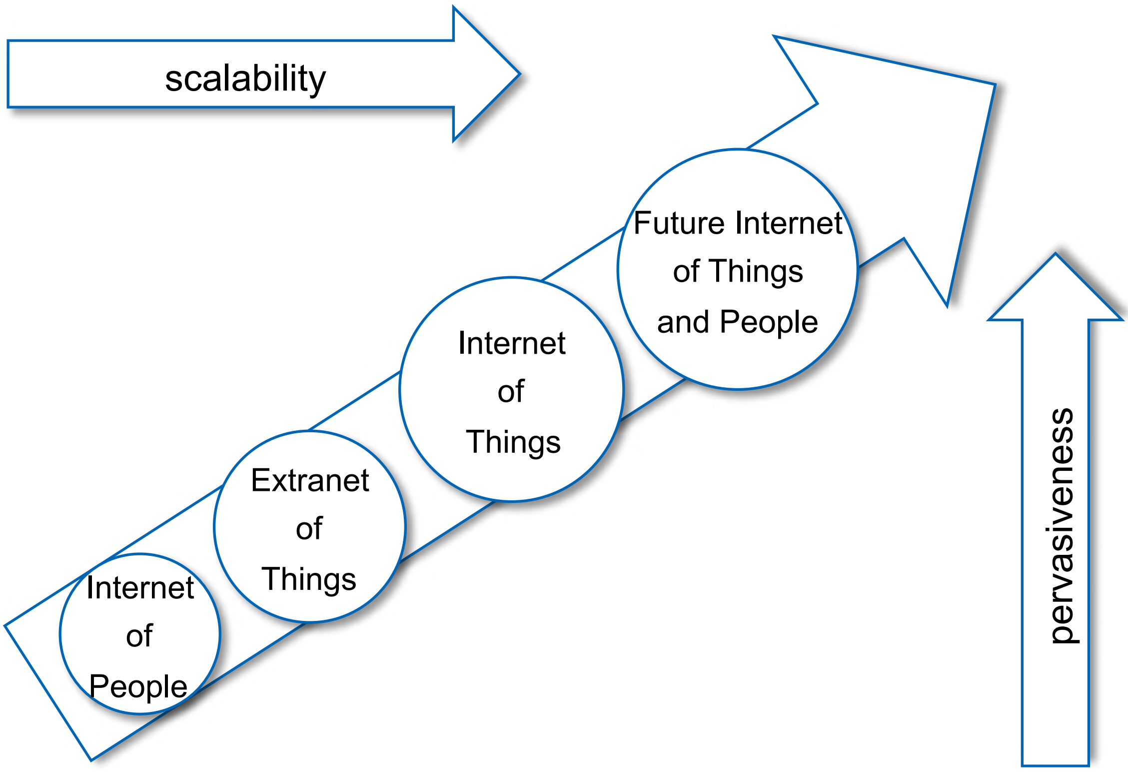
Source: compiled by author

Appendix 3. **Measurement model (outer model) of the structural equation model**



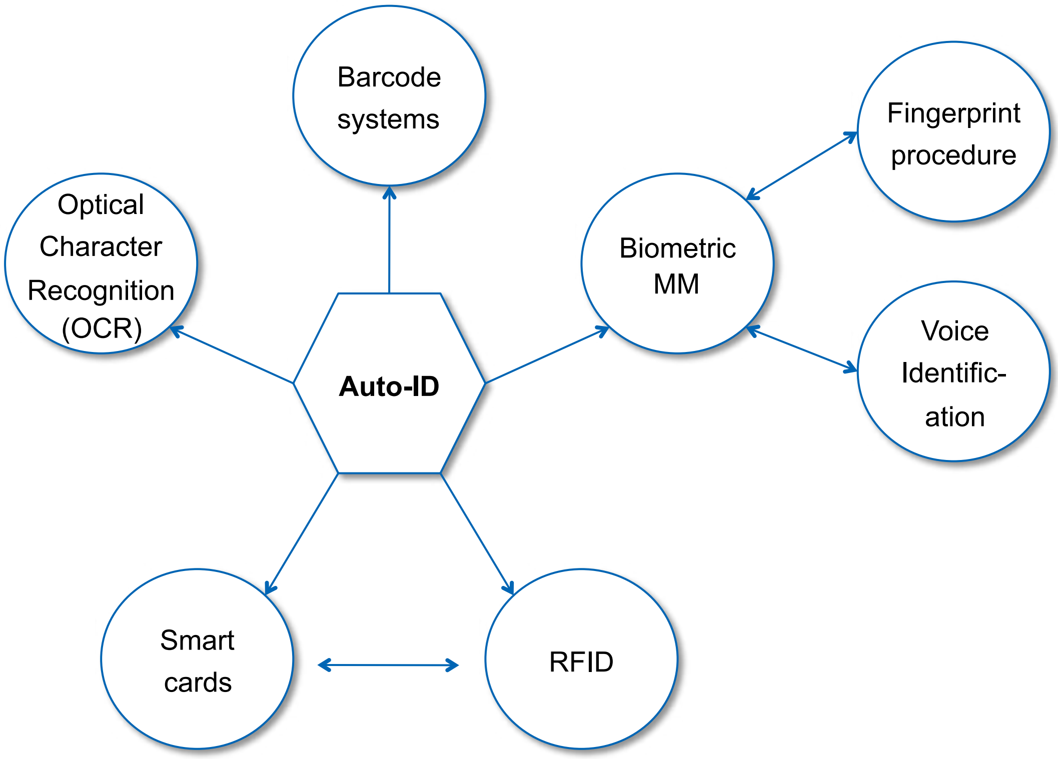
Source: derived by author from Akkermans et al. (2003), p. 286, Falke (2013), p. 2, Chopra and Meindl (2013), p. 56, Yücesan (2007), p. 131, and Schönemann (2011), p. 38

Appendix 4. **Elements of supply chain management (year 2015)**



Source: derived by author from Uckelmann et al. (2011), pp. 3

Appendix 5. **Schematic development process of Internet of Things concept (year 2011)**

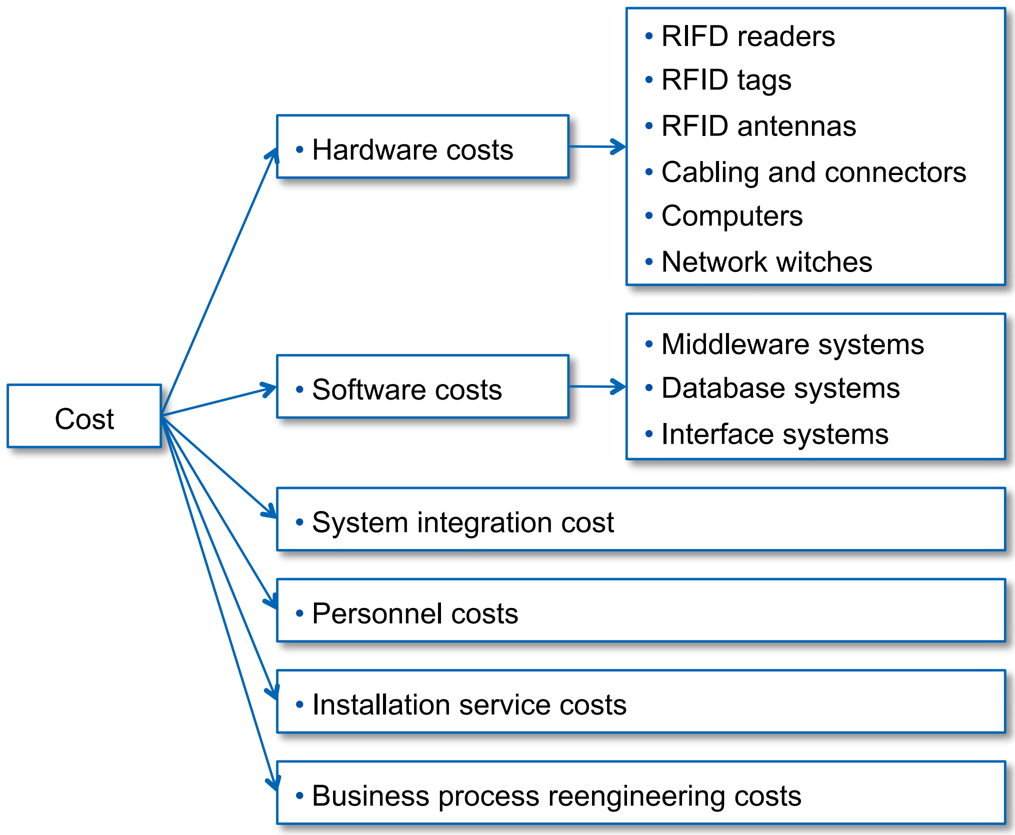


Source: derived by author from Banks et al. (2007), pp. 3

Appendix 6. **Overview of the most important Auto-ID procedures (year 2012)**

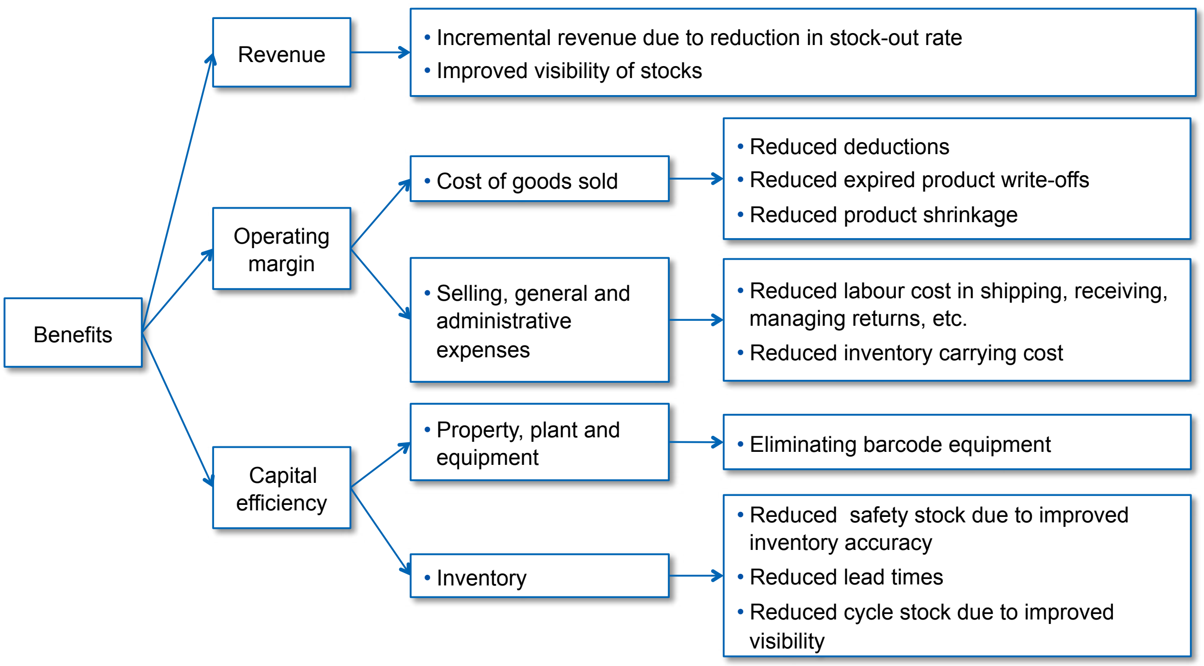
Source: derived by author from Morrison (2010), p. 266 and Formiga et al. (2011), p. 25

Appendix 7. **Structure of 2D bar codes (QR code and Data Matrix code) in 2013**



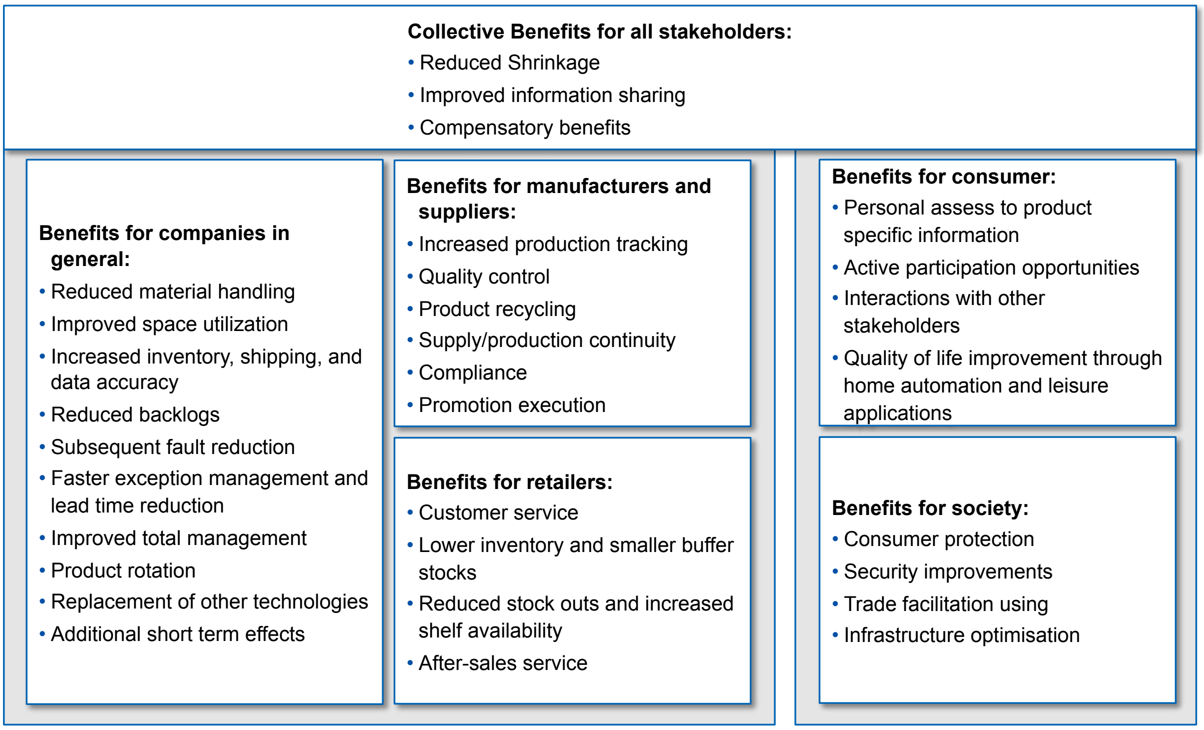
Source: derived by author from Banks et al. (2007), pp. 174 and Sarac et al. (2010), p. 91

Appendix 8. **Cost factors of Radio Frequency Identification (RFID) technology (in 2015)**



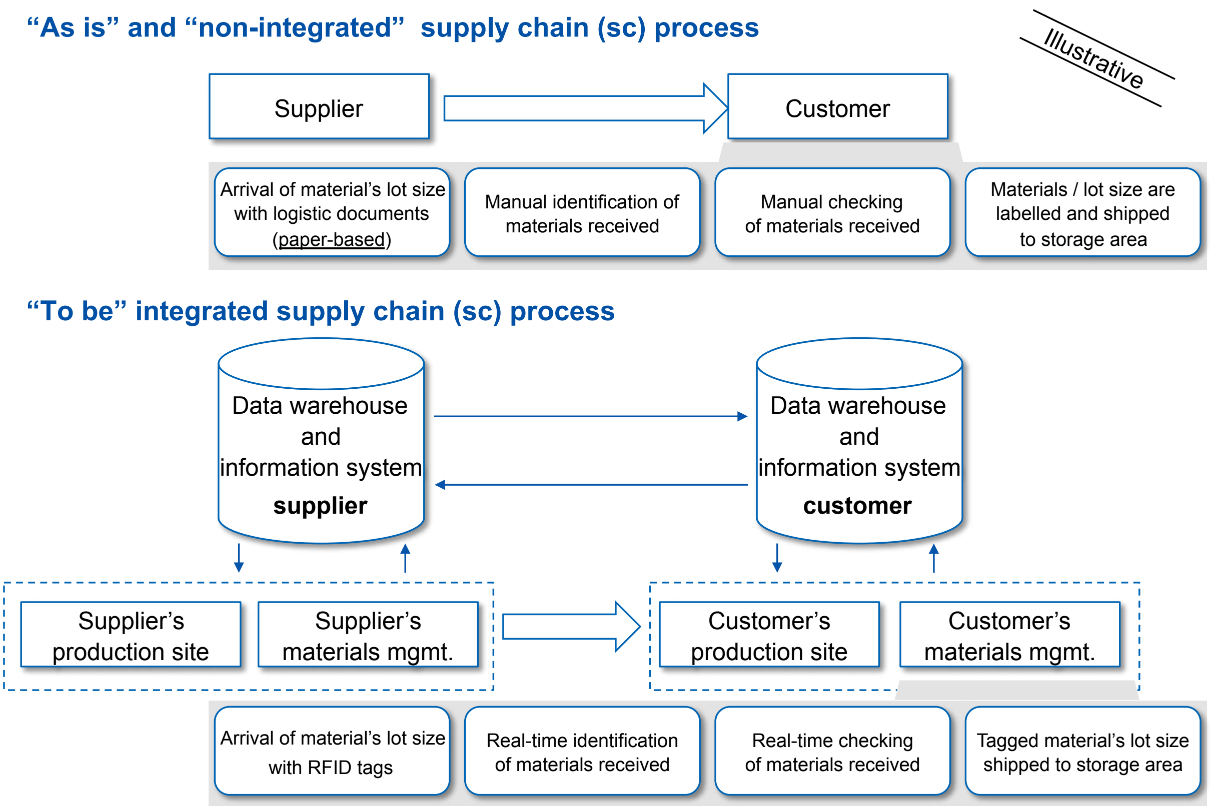
Source: derived by author from Leung et al. (2007), p. 55

Appendix 9. **Benefit factors of Radio Frequency Identification technology (in 2015)**



Source: derived by author from Uckelmann (2012), pp. 83 and Uckelmann and Schulz-Reiter (2011), pp. 239

Appendix 10. **Locus of impact from benefits of RFID technology and IoT (in 2015)**



Source: derived from Bottani and Rizzi (2008), pp. 55 and Hinkka and Tätilä (2013), p. 412

Appendix 11. **Schematic 'RFID reengineered' receiving process within integrated SC**

Overview Interviews

No.	Title	Name	Organization	City	Position	Appointment request	Appointment Day	Appointment Date	Appointment Duration	Report written Day	Report written Date	Report sent to interviewee Day	Report sent to interviewee Date	Type of Interview	Recorded	Email	Information
1	Dr.	known to the author	EuroData Council	Naumburg, Germany	President Engineering (Geschäftsführer Technik)	10.11.13	Tuesday	12.11.21013, 2 pm	1:14 hours	Wednesday	12.11.2013	Saturday	16-Nov-13	phone	audio-taped	known to the author	http://www.eurodatacouncil.org
2			Federal Office of Information Security (Bundesamt für Sicherheit der Informationstechnik)	Bonn, Germany	Dipl.-Ing. Security eID-Applications (Dipl.-Ing. Sicherheit eID-Anwendungen)	10.11.13	Thursday	21.11.2013, 2 pm	1:50 hours	Thursday	21.11.2013	Saturday	23-Nov-13	personal	audio-taped		https://www.bsi.bund.de
3	Dr.		admoVa GmbH	Bad Camberg, Germany	Executive Director (Geschäftsführer)	20.11.13	Tuesday	03.13.2013, 2 pm	0:37 hours	Tuesday	3.12.2013	Sunday	8-Dez-13	phone	audio-taped		http://www.admova.com
4			TAGnology Systems GmbH	Karlsruhe, Gemany	Project Manager	10.11.13	Thursday	05.12.2013, 2 pm	1:24 hours	Thursday	5.12.2013	Sunday	8-Dez-13	phone	audio-taped		http://www.tagnology.com
5			FIR (Institute for Industrial Management) at the RWTH Aachen University	Aachen, Germany	Head of Research Unit Information Technology Management within Department Information Management (Dipl.-Wi.-Ing. - Leiter Fachgruppe Informationstechnologiemanagement Informationsmanagement)	10.11.13	Wednesday	11.12.2013, 10 am	1:33 hours	Wednesday	11.12.2013	Saturday	14-Dez-13	phone	audio-taped		http://www.fir.rwth-aachen.de
6			ThyssenKrupp IT Service	Essen, Germany	Manager Application Services - RFID / Supply Chain Visibility	20.11.2013 (Dr. Breker, VP Logistics)	Friday	13.12.2013, 1 pm	1:55 hours	Friday	13.12.2013	Saturday	14-Dez-13	personal	audio-taped		http://www.thyssenkrupp.com
7			European EPC Competence Center GmbH (EECC)	Neuss, Germany	General Manager (Geschäftsführer)	15.12.13	Friday	10.01.2014, 2:30 pm	3:00 hours	Saturday	11.1.2014	Sunday	12-Jan-14	personal	audio-taped		
8			GS1 Germany GmbH	Cologne, Germany	Manager Identification/Data Carrier GS1 Standards + Product	15.12.13	Tuesday	14.01.2014, 2 pm	2:00 hours	Tuesday	14.1.2014	Thursday	16-Jan-14	personal	audio-taped		http://www.gs1-germany.de
9			RWE Power AG	Grevenbroich, Germany	Head of Material Management (Leiter Materialwirtschaft)	15.04.14	Wednesday	23.04.2014, 2 pm	2:00 hours	Friday	26.4.2014	Monday	29-Apr-14	personal	audio-taped		http://www.rwe.com/
10			ESE World B.V.	Berlin, Germany	Manager Supply Chain Planning & Coordination	29.07.14	Sunday	29.07.2014, 11:30 am	0:55 hours	Monday	11.8.2014	Wednesda	13-Aug-14	personal	audio-taped		http://www.ese.com/ese-world
11			Stadtwerke Neuwied GmbH	Neuwied, Germany	Head of Procurement / Materialmanagement	08.09.14	Friday	25.10.2014, 6 pm	1:00 hours	Monday	27.10.2014	Tuesday	27-Okt-14	personal	not audio-taped		http://www.swn-neuwied.de
12			Lechwerke AG	Augsburg, Germany	Organization - Projects	07.10.14	Monday	27.10.2014, 1 pm	1:30 hours	Monday	27.10.2014	Tuesday	27-Okt-14	phone	audio-taped		http://www.lew.de
13			The North Rhine-Westphalia Commissioner for Data Protection and Freedom of Information - LDI NRW (Landesbeauftragter für Datenschutz und Informationsfreiheit Nordrhein-Westfalen)	Düsseldorf, Germany	Responsible offical for Information and Communication Technology Technological-organizational consultant	15.12.2013 second try 16.10.2014	Friday	07.11.2014, 1:00 pm	1:00 hours	Saturday	8.11.2014	Monday	29-Apr-14	personal	not audio-taped		https://www.ldi.nrw.de/
14			Deutsche Post / DHL DHL Innovation Center	Bonn/Troisdorf, Germany		2013/2014											
15			Metro Group	Düsseldorf, Germany		2013/2014											

compiled by author

Source: compiled by author. Semi-structured interviews are conducted by the author of this thesis between November 2013 and November 2015.

Appendix 12. **Detailed information on the execution of semi-structured interviews**

Source: compiled by author. Semi-structured interviews are conducted by the author of this thesis between November 2013 and November 2015.

Appendix 13. **Interview partners for semi-structured interviews**

Dissertation Stefan Willutzky - Interview Guide/Protocol – Name Surname, Company XX/2014

Interview Guide

Date: XX.XX.2014, X:00 – X:00 pm

Place: X, Germany

(phone call) personal / (not) audio-taped

Background of interviewee

Title	X
Last Name	X
Surname	X
Company/Organization	X
City	X, Germany
Division	X
Industry	X
Job Title	X
Years with Company	X years
Years in Position	X years
Years in Purchasing	X years
No. of employees company	X employees
No. of employees department	X years
Sales in last year (2012)	X Mio. Euro
	https://www.internet-page.de/

1

Source: compiled by author. Semi-structured interviews are conducted by the author of this thesis between November 2013 and November 2015.

Appendix 14. **Interview guide / protocol**

Dissertation Stefan Willutzky - Interview Guide/Protocol – Name Surname, Company XX/2014

Introduction of interviewer and interviewee

- Background of interviewer
- Background of interviewee

Background regarding education?

Background regarding and work experience?

What is the major business of your company?

2

Source: compiled by author. Semi-structured interviews are conducted by the author of this thesis between November 2013 and November 2015.

Appendix 14. (continuation) **Interview guide / protocol**

Dissertation Stefan Willutzky - Interview Guide/Protocol – Name Surname, Company XX/2014

Introduction of topic

- Actual (past years) rising interest in innovation management (e.g. Auto-ID technologies innovations) within business and supply chain management
- Highlighting the importance of inter-organizational innovations
- Vision of Future Internet of Things and People

  (Intranet or even Extranet of Things to a fully integration of virtual and real things within the Internet of Things - IoT)

  Definition IoT - Vermesan and Friess (2011):

  "The Internet of Things is formed by the networked interconnection of everyday objects and is involving self configuring wireless networks of sensors that create a world where everything in it sends information to other objects and to people. In this world, everything is tagged and communicating provides information and knowledge."
- Concept of cyber-physical systems
- German political / economical concept of "Industrie 4.0"

  Smart Factory, Smart Logistics, Smart Products
- Increasing focus on Auto-ID technologies; price for RFID chips is decreasing

-> Innovation in inter-organizational projects between supply chain partners (further supply chain collaboration, projects of Auto-ID and especially RFID technology) is still a hot topic in SCM? (however, hype over?)

3

Source: compiled by author. Semi-structured interviews are conducted by the author of this thesis between November 2013 and November 2015.

Appendix 14. (continuation) **Interview guide / protocol**

Dissertation Stefan Willutzky - Interview Guide/Protocol – Name Surname, Company XX/2014

(Briefly) **Experience (research/operating) with innovation management in SCM and for example with Auto-ID technology**

- What is your (research/operating) experience with the adoption of innovation in SCM and Auto-ID technologies?

  "in general"

- In which innovation projects (e.g. Auto-ID projects) have you been involved?
- Who started / forced / supported the project?

  (top mgmt., customer/supplier, business department, IT department)

- What has been / is the result of these projects? (benefits/costs/shortcomings)

- What are the risks regarding security issues?
  How did you / do deal with these issues in implementation projects?
  (further internet-based integration towards Internet of ...)

  Background to RFID innovation projects:
  Due to an expensive and time-consuming RFID technology implementation on lager scale, most companies require a relatively rigorous business case prior to a decision whether, how, and when to implement this innovative information technology. … This thesis will provide an analysis of cost and benefits of RFID technology within the inter-organizational supply chain in the German utility industry.

4

Source: compiled by author. Semi-structured interviews are conducted by the author of this thesis between November 2013 and November 2015.

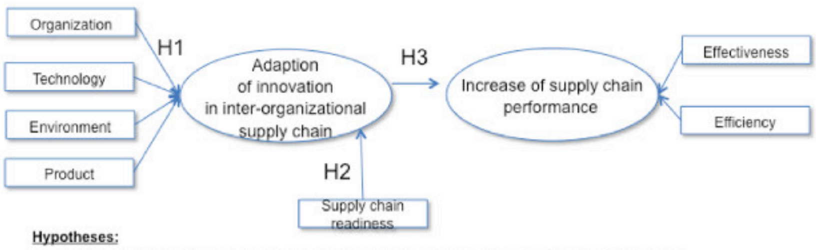
Appendix 14. (continuation) **Interview guide / protocol**

Dissertation Stefan Willutzky - Interview Guide/Protocol – Name Surname, Company XX/2014

Research Question

Does a supply chain management innovation increase supply chain performance?

Revised research model and hypotheses (from Excel file) are presented



Hypotheses:

H0: An innovation in the intra-organizational supply chain has an impact on supply chain performance

H1: The factors organization, technology, environment and product positively increase the utilization of a SCM innovation within inter-organizational supply chains

H2: Supply chain readiness has a supporting effect on supply chain performance

H3: The adaption of an innovation in inter-organizational supply chain increases supply chain performance

Factors for adoption of innovation in intra-organizational supply chains are presented:

Factors are presented – from Excel file

Factors & sub-factors for innovation in inter-organizational supply chain management

Factor	Sub-factor				
Organization	Financial resources	Top management	Company size		
Environment	Competitive pressure	Innovation maturity	Industry environment	Uncertainty of environment	
Technology	Complexity of technology	Compatibility of technology	Visible obstacle		
Product	Product complexity	Product availability	Product life-cycle management	Product attributes	
Supply chain readiness	Bargaining power	Initiator	Trust	Partner readiness	Inter-organ. dependencies
Supply chain effectiveness	Measurement scale deducted from literature and stated in four questions				
Supply chain efficiency	Measurement scale deducted from literature and stated in four questions				

5

Source: compiled by author. Semi-structured interviews are conducted by the author of this thesis between November 2013 and November 2015.

Appendix 14. (continuation) **Interview guide / protocol**

Dissertation Stefan Willutzky - Interview Guide/Protocol – Name Surname, Company XX/2014

Supply Chain Management (SCM)

- direct supply chain -> extended supply chain -> ultimate supply chain
- further integration of supply chains

Due to interviewing experts from different business / technological experts:

- What is your "viewing angle" / perspective towards SCM / logistic topics?
- How can your expert knowledge contribute to improve SCM (and other fields of business / IT)?

Bar code Technology

-> related to SCM

-> related to other business areas / "best practice" / "thinking outside the box"

Bar code: one-dimensional / two-dimensional, data matrix / three dimensional

- What are the reasons of success of bar code technology from your point of view?

- Benefits - what are...?
  (theoretical knowledge or practical experience)

- Cost - what are ...?
  (theoretical knowledge or practical experience)

- What are the limitations of bar code technology from your point of view?
  Technological factors / -> impact
  Business factors / ->impact?

- How do you evaluate security issues of bar code technology?
  (information outside of packaging / direct line of sight)

6

Source: compiled by author. Semi-structured interviews are conducted by the author of this thesis between November 2013 and November 2015.

Appendix 14. (continuation) **Interview guide / protocol**

Radio Frequency Identification (RFID) Technology

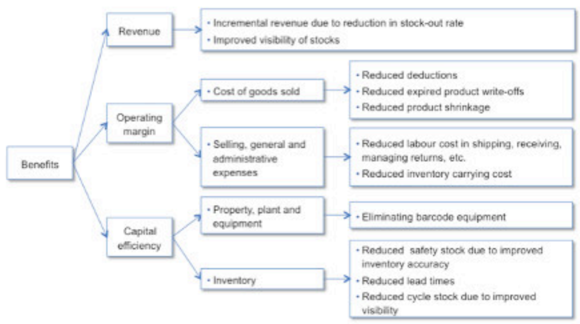
Def. RFID in its simplest form:

RFID is the process and physical infrastructure by which a unique identifier, within a predefined protocol definition, is transferred from a device to a reader via radio frequency waves

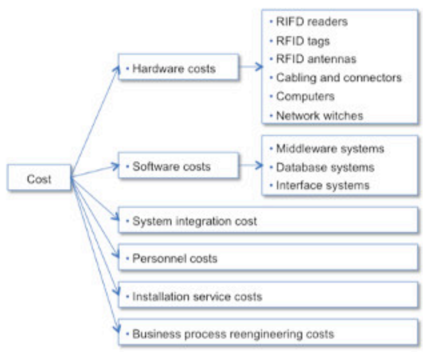
-> related to SCM

-> related to other business areas / "best practice" / "thinking outside the box"

- Benefits - what are ...?



- Cost - what are ...?



- What are the limitations of RFID technology from your point of view?

  Technological factors / -> impact

  Business factors / ->impact?

Source: compiled by author. Semi-structured interviews are conducted by the author of this thesis between November 2013 and November 2015.

Appendix 14. (continuation) **Interview guide / protocol**

- How do you evaluate security issues of RFID technology?
  (information assessable even without direct line of sight)

- Challenges and Future for RFID technology
  Technological aspects (effectiveness)
  Economical aspects (efficiency)
  Security issues

- Numerous researchers formulate critique of the Internet of Things.

  Rob van Kranenburg (2008) examines impact of ambient technology and the all-seeing network of RFID on the wider society. Main critique related to the Internet of Things focuses on privacy and security.

8

Source: compiled by author. Semi-structured interviews are conducted by the author of this thesis between November 2013 and November 2015.

Appendix 14. (continuation) **Interview guide / protocol**

Dissertation Stefan Willutzky - Interview Guide/Protocol – Name Surname, Company XX/2014

Measurement in supply chain management

Intra-organizational supply chain management

- Effectiveness
- Efficiency

Introduction of questionnaire for the survey

Survey structure and questions are presented from pdf file

-> Actual research model and questionnaire is presented and discussed in detail.

-> any further categories relevant for implementation innovations in SCM (incl. new technologies) in inter-organisation supply chains are mentioned by the interviewee.

Finish interview

- Anything you want to add to this research interview?

- Willingness/Openness

  to answer further questions, where required?

  to answer questionnaire?

- Feedback regarding further research and research results

Thank you!

9

Source: compiled by author. Semi-structured interviews are conducted by the author of this thesis between November 2013 and November 2015.

Appendix 14. (continuation) **Interview guide / protocol**

WZ 2008 Kode	WZ 2008 - Bezeichnung (a. n. g. = anderweitig nicht genannt)	ISIC Rev. 4
D	ABSCHNITT D – ENERGIEVERSORGUNG	
35	**Energieversorgung**	
35.1	**Elektrizitätsversorgung**	
35.11	Elektrizitätserzeugung	3510*
35.11.1	Elektrizitätserzeugung ohne Verteilung	
35.11.2	Elektrizitätserzeugung mit Fremdbezug zur Verteilung	
35.11.3	Elektrizitätserzeugung ohne Fremdbezug zur Verteilung	
35.12	Elektrizitätsübertragung	3510*
35.12.0	Elektrizitätsübertragung	
35.13	Elektrizitätsverteilung	3510*
35.13.0	Elektrizitätsverteilung	
35.14	Elektrizitätshandel	3510*
35.14.0	Elektrizitätshandel	
35.2	**Gasversorgung**	
35.21	Gaserzeugung	3520*
35.21.1	Gaserzeugung ohne Verteilung	
35.21.2	Gaserzeugung mit Fremdbezug zur Verteilung	
35.21.3	Gaserzeugung ohne Fremdbezug zur Verteilung	
35.22	Gasverteilung durch Rohrleitungen	3520*
35.22.0	Gasverteilung durch Rohrleitungen	
35.23	Gashandel durch Rohrleitungen	3520*
35.23.0	Gashandel durch Rohrleitungen	
35.3	**Wärme- und Kälteversorgung**	
35.30	Wärme- und Kälteversorgung	3530
35.30.0	Wärme- und Kälteversorgung	

102 Statistisches Bundesamt, WZ 2008

Source: German Federal Statistical Office (2008), p. 102

Appendix 15. **Nomenclature of economic activities in Germany in 2008**

"Innovationen in der Lieferkette zwischen Unternehmen"

Einleitung

Sehr geehrte Dame, sehr geehrter Herr,

vielen Dank, dass Sie an meiner Umfrage teilnehmen.

Diese Forschungsarbeit im Rahmen meiner Promotion weist folgende Merkmale auf:
- Innovationen in der Lieferkette / Supply-Chain-Management (SCM) zwischen Unternehmen
- vergleichende Abfrage der Innovativen Barcode und RFID (Radio Frequency Identifikation)
- Grundgesamtheit der Umfrage sind konventionelle deutsche Elektrizitätserzeuger mit >10 MW elektr. Netto-Nennleistung.

Vor dem Hintergrund der aktuellen Vision „Industrie 4.0“ der deutschen Wirtschaft wird diese Umfrage die Parameter für die Umsetzung einer Innovation in der Lieferkette / Supply-Chain-Management (SCM) zwischen Unternehmen untersuchen.
Hierbei werden u.a. die Anwendung von Barcode und RFID Technologie mit Ihren Handelspartnern vergleichend untersucht.

Die Beantwortung des Fragebogens erfolgt anonym und dauert ca. 10 Minuten.
Alle Teilnehmer können am Ende ihre Email-Adresse angeben und erhalten eine Zusammenfassung der Ergebnisse.
Bei weiteren Fragen können Sie mich gerne unter der Email-Adresse Stefan.Willutzky_Promotion@gmx.de kontaktieren.

Vielen Dank für Ihre Unterstützung!!!

Stefan Willutzky

Page 1

Source: compiled by author. Questionnaire survey is applied with supply chain members of the German electricity power generation industry between November 2014 to February 2015.

Appendix 16. **Survey (presentation in the software tool SurveyMonkey)**

"Innovationen in der Lieferkette zwischen Unternehmen"

Organisation des Unternehmens

Bitte geben Sie Ihren Zustimmungsgrad zur Aussage an:

1. Das Unternehmen stellt ausreichend finanzielle Ressourcen zur Einführung einer Supply-Chain-Management (SCM) Innovation zur Verfügung.

	Stimme nicht zu		Neutral		Stimme zu
Barcode	◯	◯	◯	◯	◯
RFID	◯	◯	◯	◯	◯
allgemein	◯	◯	◯	◯	◯

2. Das Management unterstützt nachhaltig die Einführung und Nutzung einer SCM Innovation.

	Stimme nicht zu		Neutral		Stimme zu
Barcode	◯	◯	◯	◯	◯
RFID	◯	◯	◯	◯	◯
allgemein	◯	◯	◯	◯	◯

3. Es werden ausreichend personelle Ressourcen durch das Management zur Einführung einer SCM Innovation bereitgestellt.

	Stimme nicht zu		Neutral		Stimme zu
Barcode	◯	◯	◯	◯	◯
RFID	◯	◯	◯	◯	◯
allgemein	◯	◯	◯	◯	◯

4. Bitte geben Sie - zur Einordnung der Unternehmensgröße - die Zahl der Mitarbeiter an. (Basis letztes Geschäftsjahr)

◯ keine Angabe
◯ 0-99
◯ 100-199
◯ 200-499
◯ 500-999
◯ 1.000-1.999
◯ 2.000 und mehr

Page 2

Source: compiled by author. Questionnaire survey is applied with supply chain members of the German electricity power generation industry between November 2014 to February 2015.

Appendix 16. (continuation) **Survey (presentation in the software tool SurveyMonkey)**

"Innovationen in der Lieferkette zwischen Unternehmen"

5. Bitte geben Sie - zur Einordnung der Unternehmensgröße - den Umsatz des Unternehmens an.
(in Milionen Euro - Basis letztes Geschäftsjahr)

◯ keine Angabe
◯ 0-49
◯ 50-99
◯ 101-299
◯ 300-499
◯ 500-999
◯ 1.000 und mehr

Page 3

Source: compiled by author. Questionnaire survey is applied with supply chain members of the German electricity power generation industry between November 2014 to February 2015.

Appendix 16. (continuation) **Survey (presentation in the software tool SurveyMonkey)**

"Innovationen in der Lieferkette zwischen Unternehmen"

Umfeld des Unternehmens

Bitte geben Sie Ihren Zustimmungsgrad zur Aussage an:

6. Der Wettbewerbsdruck in der Branche "Stromerzeugung" erhöht die Einführungsquote einer SCM Innovation.

	Stimme nicht zu		Neutral		Stimme zu
Barcode	○	○	○	○	○
RFID	○	○	○	○	○
allgemein	○	○	○	○	○

7. Die Entwicklungsreife einer SCM Innovation ist entscheidend für deren Einführung und Verbreitung.

	Stimme nicht zu		Neutral		Stimme zu
Barcode	○	○	○	○	○
RFID	○	○	○	○	○
allgemein	○	○	○	○	○

8. Die Marktbesonderheiten in der Branche "Stromerzeugung" beeinflussen die Einführung einer SCM Innovation.

	Stimme nicht zu		Neutral		Stimme zu
Barcode	○	○	○	○	○
RFID	○	○	○	○	○
allgemein	○	○	○	○	○

9. Die Marktunsicherheit, resultierend u.a. aus dem extremen Wandel der Branche "Stromerzeugung" (Stichwort Energiewende), behindert die Einführung einer SCM Innovation.

	Stimme nicht zu		Neutral		Stimme zu
Barcode	○	○	○	○	○
RFID	○	○	○	○	○
allgemein	○	○	○	○	○

Page 4

Source: compiled by author. Questionnaire survey is applied with supply chain members of the German electricity power generation industry between November 2014 to February 2015.

Appendix 16. (continuation) **Survey (presentation in the software tool SurveyMonkey)**

"Innovationen in der Lieferkette zwischen Unternehmen"

Technologie

Bitte geben Sie Ihren Zustimmungsgrad zur Aussage an:

10. Eine hohe Komplexität einer SCM Innovation behindert deren Einführung, z.B. aufgrund des höheren Einführungsaufwands.

	Stimme nicht zu		Neutral		Stimme zu
Barcode	○	○	○	○	○
RFID	○	○	○	○	○
allgemein	○	○	○	○	○

11. Die Einführung der SCM Innovation ist organisatorisch vereinbar mit dem "Handeln der Mitarbeiter".

	Stimme nicht zu		Neutral		Stimme zu
Barcode	○	○	○	○	○
RFID	○	○	○	○	○
allgemein	○	○	○	○	○

12. Die Einführung der SCM Innovation ist technologisch vereinbar mit dem "Handeln der Mitarbeiter".

	Stimme nicht zu		Neutral		Stimme zu
Barcode	○	○	○	○	○
RFID	○	○	○	○	○
allgemein	○	○	○	○	○

13. Das Unternehmen hat Mitarbeiter und Wissen zur Verfügung, um eine SCM Innovation einzuführen.

	Stimme nicht zu		Neutral		Stimme zu
Barcode	○	○	○	○	○
RFID	○	○	○	○	○
allgemein	○	○	○	○	○

14. Es liegen erkennbare Umsetzungshindernisse vor, die eine erfolgreiche Einführung einer SCM Innovation hemmen.
(z.B. keine verfügbare IT Infrastruktur zwischen den Unternehmen, (Personal-) Datenschutz, Fehlerquote der Leserate, fehlende Normen/Standards)

	Stimme nicht zu		Neutral		Stimme zu
Barcode	○	○	○	○	○
RFID	○	○	○	○	○
allgemein	○	○	○	○	○

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Source: compiled by author. Questionnaire survey is applied with supply chain members of the German electricity power generation industry between November 2014 to February 2015.

Appendix 16. (continuation) **Survey (presentation in the software tool SurveyMonkey)**

"Innovationen in der Lieferkette zwischen Unternehmen"

Produkt Faktoren

Bitte geben Sie Ihren Zustimmungsgrad zur Aussage an:

15. Ihre große Anzahl von Materiallieferanten erhöht die Komplexität der Einführung einer SCM Innovation.

	Stimme nicht zu		Neutral		Stimme zu
Barcode					
RFID					
allgemein					

16. Die regelmäßig wechselnden Anforderungen Ihrer Schlüssellieferanten erhöhen die Komplexität der Einführung einer SCM Innovation.

	Stimme nicht zu		Neutral		Stimme zu
Barcode					
RFID					
allgemein					

17. Die Verfügbarkeit von Ersatzteilen, welche notwendig für die Instandsetzungs- und Revisionsmaßnahmen sind, kann durch eine SCM Innovation unterstützt werden.

	Stimme nicht zu		Neutral		Stimme zu
Barcode					
RFID					
allgemein					

18. Das Produktlebenszyklus-Management - z.B. die Verfolgung von Reparaturen und Einbaustellen bei Ersatzteilen - kann durch eine SCM Innovation unterstützt werden.

	Stimme nicht zu		Neutral		Stimme zu
Barcode					
RFID					
allgemein					

19. Geringwertige Verbrauchsmaterialien sind kaum relevant für die Einführung einer SCM Innovation.

	Stimme nicht zu		Neutral		Stimme zu
Barcode					
RFID					
allgemein					

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Source: compiled by author. Questionnaire survey is applied with supply chain members of the German electricity power generation industry between November 2014 to February 2015.

Appendix 16. (continuation) **Survey (presentation in the software tool SurveyMonkey)**

"Innovationen in der Lieferkette zwischen Unternehmen"

Bereitschaft der Lieferkette

Bitte geben Sie Ihren Zustimmungsgrad zur Aussage an:

20. Eine dominierende Verhandlungsmacht/Marktpositionierung eines Handelspartners beeinflusst positiv die Einführung einer SCM Innovation.

	Stimme nicht zu		Neutral		Stimme zu
Barcode	○	○	○	○	○
RFID	○	○	○	○	○
allgemein	○	○	○	○	○

21. Ein Handelspartner initiiert die Einführung einer SCM Innovation.

	Stimme nicht zu		Neutral		Stimme zu
Barcode	○	○	○	○	○
RFID	○	○	○	○	○
allgemein	○	○	○	○	○

22. Vertrauen zu Ihren Handelspartnern erleichtert den Informationsaustauch und die Einführung einer SCM Innovation.

	Stimme nicht zu		Neutral		Stimme zu
Barcode	○	○	○	○	○
RFID	○	○	○	○	○
allgemein	○	○	○	○	○

23. Es liegen gemeinsame Prozeduren, Routinen und Normen zu Ihren Handelspartnern vor, die die Einführung einer SCM Innovation unterstützen.

	Stimme nicht zu		Neutral		Stimme zu
Barcode	○	○	○	○	○
RFID	○	○	○	○	○
allgemein	○	○	○	○	○

24. Es existieren strategische Partnerschaften zu Lieferanten, welche die Einführung einer SCM Innovation unterstützen.

	Stimme nicht zu		Neutral		Stimme zu
Barcode	○	○	○	○	○
RFID	○	○	○	○	○
allgemein	○	○	○	○	○

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Source: compiled by author. Questionnaire survey is applied with supply chain members of the German electricity power generation industry between November 2014 to February 2015.

Appendix 16. (continuation) **Survey (presentation in the software tool SurveyMonkey)**

"Innovationen in der Lieferkette zwischen Unternehmen"

Leistung der Lieferkette

Bitte bewerten Sie die Leistungsfähigkeit der Lieferkette nach Einführung von SCM Innovationen.

25. Verspätete, beschädigte oder unvollzählige Lieferungen reduzieren sich durch die Einführung einer SCM Innovation.

	Stimme nicht zu		Neutral		Stimme zu
Barcode	○	○	○	○	○
RFID	○	○	○	○	○
allgemein	○	○	○	○	○

26. Die Fähigkeit zusätzlich wertschaffende Serviceleistungen anzubieten erhöht sich durch die Einführung einer SCM Innovation.
(z.B. Verfügbarkeit von Informationen in der Lieferkette /"Track and Trace")

	Stimme nicht zu		Neutral		Stimme zu
Barcode	○	○	○	○	○
RFID	○	○	○	○	○
allgemein	○	○	○	○	○

27. Die Fähigkeit schnell auf neue Kundenanforderungen bzw. Bedarfsänderungen zu reagieren erhöht sich durch die Einführung einer SCM Innovation.

	Stimme nicht zu		Neutral		Stimme zu
Barcode	○	○	○	○	○
RFID	○	○	○	○	○
allgemein	○	○	○	○	○

28. Die Fähigkeit Bedarfsanfragen pünktlich zum Bedarfszeitpunkt zu liefern erhöht sich durch die Einführung einer SCM Innovation.

	Stimme nicht zu		Neutral		Stimme zu
Barcode	○	○	○	○	○
RFID	○	○	○	○	○
allgemein	○	○	○	○	○

29. Die Fähigkeit Bedarfsanfragen in korrekten Bedarfsmengen zu liefern erhöht sich durch die Einführung einer SCM Innovation.

	Stimme nicht zu		Neutral		Stimme zu
Barcode	○	○	○	○	○
RFID	○	○	○	○	○
allgemein	○	○	○	○	○

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Source: compiled by author. Questionnaire survey is applied with supply chain members of the German electricity power generation industry between November 2014 to February 2015.

Appendix 16. (continuation) **Survey (presentation in the software tool SurveyMonkey)**

"Innovationen in der Lieferkette zwischen Unternehmen"

30. Die Fähigkeit variable Bedarfsmengen zuverlässig zu liefern erhöht sich durch die Einführung einer SCM Innovation.

	Stimme nicht zu		Neutral		Stimme zu
Barcode	○	○	○	○	○
RFID	○	○	○	○	○
allgemein	○	○	○	○	○

31. Die Gesamtkosten der Lieferkette reduzieren sich durch die Einführung einer SCM Innovation.

	Stimme nicht zu		Neutral		Stimme zu
Barcode	○	○	○	○	○
RFID	○	○	○	○	○
allgemein	○	○	○	○	○

32. Die Sicherheitsbestände in der Lieferkette reduzieren sich durch die Einführung einer SCM Innovation.

	Stimme nicht zu		Neutral		Stimme zu
Barcode	○	○	○	○	○
RFID	○	○	○	○	○
allgemein	○	○	○	○	○

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Source: compiled by author. Questionnaire survey is applied with supply chain members of the German electricity power generation industry between November 2014 to February 2015.

Appendix 16. (continuation) **Survey (presentation in the software tool SurveyMonkey)**

"Innovationen in der Lieferkette zwischen Unternehmen"

Allgemeine Informationen

33. Stellt der Betrieb des Bestandskraftwerkes die Kernkompetenz (Elektrizitätserzeugung) Ihres Unternehmens dar?

- ◯ ja
- ◯ nein

abweichende Kernkompetenz Ihres Unternehmens: (freiwillige Angabe)

34. Bitte benennen Sie Ihre Position im Unternehmen:

- ◯ Abteilungsleiter (Beschaffung / Materialwirtschaft / Produktion)
- ◯ Teamleiter (Beschaffung / Materialwirtschaft / Produktion)
- ◯ Angestellter (Beschaffung / Materialwirtschaft / Produktion)
- ◯ andere Tätigkeit
- ◯ Keine Angabe

35. Bitte geben Sie die Zeitdauer (in Jahren) in Ihrer jetzigen Position an:

- ◯ 0-1
- ◯ 2-5
- ◯ 6-10
- ◯ 11-15
- ◯ 16 und mehr

36. Bitte geben Sie die Zeitdauer (in Jahren) in der Branche an:

- ◯ 0-1
- ◯ 2-5
- ◯ 6-10
- ◯ 11-15
- ◯ 16 und mehr

37. Bitte geben Sie den aktuellen Nutzungsgrad der aufgeführten SCM Innovationen in Ihrer Lieferkette mit anderen Unternehmen an:

	Barcode	RFID
keine Anwendung	☐	☐
interne Anwendung	☐	☐
externe Anwendung (mit anderen Unternehmen)	☐	☐

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Source: compiled by author. Questionnaire survey is applied with supply chain members of the German electricity power generation industry between November 2014 to February 2015.

Appendix 16. (continuation) **Survey (presentation in the software tool SurveyMonkey)**

"Innovationen in der Lieferkette zwischen Unternehmen"

38. Bitte nennen Sie (mehrere) Gründe für die Nicht-Nutzung der aufgeführten SCM Innovationen in der Lieferkette mit anderen Unternehmen:

	Barcode	RFID
Mangelndes Bewusstsein über das Konzept	☐	☐
Zeitmangel / -defizite	☐	☐
Investitionen zu hoch	☐	☐
Unklare positive Auswirkungen	☐	☐
Lesesrate ist nicht ausreichend	☐	☐
Fehlende technologische Standards	☐	☐
Bedenken bzgl. Privatsphäre	☐	☐
Unternehmen in der Lieferkette sind nicht kooperationsbereit	☐	☐
Bedenken der Mitbestimmung / Betriebsrat	☐	☐
Andere Gründe	☐	☐

39. Vielen Dank für Ihre Teilnahme!
Gerne schicke ich Ihnen eine Zusammenfassung der Ergebnisse zu. Für Rückfragen stehe ich Ihnen jederzeit gerne zur Verfügung (Stefan.Willutzky_Promotion@gmx.de).

Sie können hier Ihre E-Mailadresse eingeben:

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Source: compiled by author. Questionnaire survey is applied with supply chain members of the German electricity power generation industry between November 2014 to February 2015.

Appendix 16. (continuation) **Survey (presentation in the software tool SurveyMonkey)**

38. Bitte nennen Sie (mehrere) Gründe für die Nicht-Nutzung der aufgeführten SCM Innovationen in der Lieferkette mit anderen Unternehmen:

	Barcode	RFID
Mangelndes Bewusstsein über das Konzept	☐	☐
Zeitmangel / -defizite	☐	☐
Investitionen zu hoch	☐	☐
Unklare positive Auswirkungen	☐	☐
Lesesrate ist nicht ausreichend	☐	☐
Fehlende technologische Standards	☐	☐
Bedenken bzgl. Privatsphäre	☐	☐
Unternehmen in der Lieferkette sind nicht kooperationsbereit	☐	☐
Bedenken der Mitbestimmung / Betriebsrat	☐	☐
Andere Gründe	☐	☐

39. Vielen Dank für Ihre Teilnahme!
Gerne schicke ich Ihnen eine Zusammenfassung der Ergebnisse zu. Für Rückfragen stehe ich Ihnen jederzeit gerne zur Verfügung (Stefan.Willutzky_Promotion@gmx.de).

Sie können hier Ihre E-Mailadresse eingeben:

40. Ist Ihr Unternehmen ein Lieferpartner der Branche "Elektrizitätserzeugung"?

○ Ja

○ Nein

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Source: compiled by author. Questionnaire survey is applied with supply chain members of the German electricity power generation industry between November 2014 to February 2015.

Appendix 17. **Survey fair trade (presentation in the software tool SurveyMonkey)**

41. In welchem Wirtschaftszweig ist Ihr Unternehmens tätig?
(gem. Auswahl der Klassifikation der Wirtschaftszweige gemäß Statistischem Bundesamt)

- ○ Bergbau und Gewinnung von Steinen und Erden (Abschnitt B)
- ○ Verabeitendes Gewerbe (Abschnitt C)
- ○ Energieversorgung (Abschnitt D)
- ○ Wasserversorung, Abwasser- und Abfallentsorgung und Beseitigung von Umweltverschmutzungen (Abschnitt F)
- ○ Baugewerbe (Abschnitt F)

Andere Klassifikationen:

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Source: compiled by author. Questionnaire survey is applied with supply chain members of the German electricity power generation industry between November 2014 to February 2015.

Appendix 17. (continuation) **Survey fair trade (presentation in the software tool SurveyMonkey)**

Mail in German (as applied in the software tool SurveyMonkey)

Send from: Stefan.Willutzky_Promotion@gmx.de

Subject: Bitte um Unterstützung: Umfrage im Rahmen meiner Promotion – Stefan Willutzky

Text:
[CustomData]

[FirstName] [LastName],

mit der Bitte um Unterstützung übersende ich Ihnen anbei meine Umfrage im Rahmen der Promotion.
Die Beantwortung des Fragebogens erfolgt anonym und dauert ca. 10 Minuten.

Link zur Umfrage:
[SurveyLink]

Meine Promotion beschäftigt sich mit den Einflussfaktoren von Innovationen im Supply Chain Management und dem Einsatz von neuen Technologien.
Weitere Informationen zu meiner Forschungsarbeit erhalten Sie in der kurzen Einleitung des Fragebogens.

Sie sind Teilnehmer der Umfrage, da Ihr Unternehmen ein Kraftwerk zur Elektrizitätserzeugung (> 10 MW Netto-Nennleistung) gemäß der Bundesnetzagentur betreibt.

Bei weiteren Fragen können Sie mich gerne unter der Email--Adresse Stefan.Willutzky_Promotion@gmx.de kontaktieren. Gerne stelle ich Ihnen die Ergebnisse meiner wissenschaftlichen Untersuchung zur Verfügung.
Vielen Dank für Ihre Unterstützung!!!
Stefan Willutzky

Hinweis:
Wenn Sie keine weiteren E-Mails von mir erhalten möchten, klicken Sie bitte auf den unten stehenden Link, und Sie werden automatisch aus der Adressenliste entfernt.
[RemoveLink]

Source: compiled by author. Questionnaire survey is applied with supply chain members of the German electricity power generation industry between November 2014 to February 2015.

Appendix 18. **Survey – initial mail (in German and English)**

Mail in English (translated from the German version)

Send from: Stefan.Willutzky_Promotion@gmx.de

Subject: Request for support: Survey during my doctoral studies – Stefan Willutzky

Text:
[CustomData]

[FirstName] [LastName],

With the request for support, I send you attached my survey during my doctoral studies. The response of the questionnaire takes place anonymously and last around 10 minutes.

Link to the survey:
[SurveyLink]

My doctoral studies addresses the influencing factors od innovations within supply chain management and the use of new technologies.
Further information about my doctoral studies are stated in a short introduction of the questionnaire.

You are a participant of the survey because your company operates a power plant for electricity generation (> 10 MW net nominal capacity) according to the Federal Network Agency

For any further question you can contact me via the email address Stefan.Willutzky_ Promotion@gmx.de. I would be please to provide you the results of my scientific research.
Thank you for your support.
Stefan Willutzky

Notice:
If you do not want to receive any further email, please click on the link below and you will be deleted automatically from the address list.
[RemoveLink]

Source: compiled by author. Questionnaire survey is applied with supply chain members of the German electricity power generation industry between November 2014 to February 2015.

Appendix 18. (continuation) **Survey – initial mail (in German and English)**

Mail in German (as applied in the software tool SurveyMonkey)

Send from: Stefan.Willutzky_Promotion@gmx.de

Subject: Erinnerung - Bitte um Unterstützung: Umfrage im Rahmen meiner Promotion – Stefan Willutzky

[CustomData]

[FirstName] [LastName],

wie Sie meiner Mail in der letzten Woche entnehmen konnten führe ich eine Umfrage durch und würde Ihre Antwort sehr zu schätzen wissen.

Hier ist ein Link zur Umfrage:
[SurveyLink]

Vielen Dank für Ihre Teilnahme - bis zum 03.12.2014!

Besten Gruß
Stefan Willutzky

Hinweis zu Remove Link:
[RemoveLink]

Source: compiled by author. Questionnaire survey is applied with supply chain members of the German electricity power generation industry between November 2014 to February 2015.

Appendix 19. **Survey – reminder 1 mail (in German and English)**

Mail in English (translated from the German version)

Send from: Stefan.Willutzky_Promotion@gmx.de

Subject: Reminder - Request for support: Survey during my doctoral studies – Stefan Willutzky

[CustomData]

[FirstName] [LastName],

As you may have read in my email last week, I currently conducting a survey and I would appreciate your response very much.

Here is the link to the survey:
[SurveyLink]

Thank you very much for participation – until 03.12.2014!

Best Regards,
Stefan Willutzky

Note to Remove Link:
[RemoveLink]

Source: compiled by author. Questionnaire survey is applied with supply chain members of the German electricity power generation industry between November 2014 to February 2015.

Appendix 19. (continuation) **Survey – reminder 1 mail (in German and English)**

Mail in German (as applied in the software tool SurveyMonkey)

Send from: Stefan.Willutzky_Promotion@gmx.de

Subject: FINAL CALL - Bitte um Unterstützung: Umfrage im Rahmen meiner Promotion – Stefan Willutzky

[CustomData]

[FirstName] [LastName],

ich bitte Sie an dieser Stelle final, um Ihre Teilnahme an meiner Umfrage im Rahmen der Promotion zu den Einflussfaktoren von Innovationen im Supply Chain Management und dem Einsatz von neuen Technologien.
Die Beantwortung des Fragebogens erfolgt anonym und dauert ca. 10 Minuten.

Link zur Umfrage:
[SurveyLink]

Die Ergebnisse meiner wissenschaftlichen Untersuchung stelle ich Ihnen gerne zur Verfügung.
Vielen Dank für Ihre Teilnahme.

Besten Gruß
Stefan Willutzky

Hinweis zu Remove Link:
[RemoveLink]

Source: compiled by author. Questionnaire survey is applied with supply chain members of the German electricity power generation industry between November 2014 to February 2015.

Appendix 20. **Survey – reminder 2 mail (in German and English)**

Mail in English (translated from the German version

Send from: Stefan.Willutzky_Promotion@gmx.de

Subject: FINAL CALL - Request for support: Survey during my doctoral studies – Stefan Willutzky

[CustomData]

[FirstName] [LastName],

I'm finally requesting you're your participation in my survey during my doctoral studies regarding the managerial impact factors for innovation in supply chain management and the adoption of new technologies.
The response of the questionnaire takes place anonymously and last around 10 minutes.

Here is the link to the survey:
[SurveyLink]

I will gladly provide you the results of my research work.
Thank you very much for participation.

Best Regards,
Stefan Willutzky

Note to Remove Link:
[RemoveLink]

Source: compiled by author. Questionnaire survey is applied with supply chain members of the German electricity power generation industry between November 2014 to February 2015.

Appendix 20. (continuation) **Survey – reminder 2 mail (in German and English)**

Appendix 21. **List of survey participants**

Company name	"Electricity generation" as core competence	Details about main industry segment	Survey sent	Survey reminder 1	Survey reminder 2	Internet page	Address / Contact details	Number of power plants	Amount of net nominal capacity (in MW)
ACR Biokraftwerk Calbe Invest GmbH & Co. KG	yes	biomass	18.11.14			http://kraftwerk-calbe.de/	ACR Biokraftwerk Calbe Invest GmbH & Co. KG Ringstr. 34 39240 Calbe / Saale Telefon: 039291/54521	1	10
Adam Opel AG	no	automotive	19.11.2014 08:45 am				Adam Opel AG Bahnhofsplatz 65423 Rüsselsheim am Main	1	112
ADM Hamburg Aktiengesellschaft	no	biomass	18.11.2014 09:15 am	27.11.14	09.12.14	http://www.oelag.de	ADM Hamburg Aktiengesellschaft Postfach 93 03 20 21083 Hamburg Tel: +49 40 7 51 94-0	1	23
AGR Abfallentsorgungsgesellschaft Ruhrgebiet mbH	yes	waste mgmt.	18.11.2014 09:15 am	27.11.14	09.12.14	http://www.agr.de/	AGR Gruppe Im Emscherbruch 11 45699 Herten Einkauf: Telefon: 02366 300-850	2	30
Aktien-Gesellschaft der Dillinger Hüttenwerke, ROGESA Roheisengesellschaft Saar steelmbH und Zentralkokerei Saar GmbH, als Bruchteilsgemeinschaft	no	metal working	18.11.2014 09:15 am	27.11.14	09.12.14	http://www.zentralkokerei.de/zks/kontakte/ansprechpartner/index.shtml.de	n/a	1	85
Allgäuer Überlandwerk GmbH	yes	electricity generation	18.11.2014 09:15 am	27.11.14	09.12.14	https://www.auew.de/	Allgäuer Überlandwerk GmbH Illerstraße 18, 87435 Kempten Tel: +49 831 2521-0	2	35
Aluminium Oxid Stade GmbH	no	metal working	18.11.2014 09:15 am	27.11.14	09.12.14	http://www.aos-stade.de	Johann-Rathje-Köser-Straße D-21683 Stade-Bützfleth Telefon: +49 (4146) 92-641	1	31
Alzkraftwerke Heider GmbH	yes	electricity generation	18.11.2014 09:15 am	27.11.14	09.12.14	http://www.alzkraftwerke-heider.de	Alzkraftwerke Heider GmbH Schwarzauer Straße 5 83308 Trostberg Telefon: +49 8621 649 81 77	1	19
AMK - Abfallentsorgungsgesellschaft des Märkischen Kreises mbH	yes	waste mgmt.	18.11.2014 09:15 am	27.11.14	09.12.14	http://www.amk-mhkw.de/	AMK Abfallentsorgungsgesellschaft des Märkischen Kreises mbH Giesestr. 10 58636 Iserlohn Tel.: 02371 / 4301 - 0	1	13
Arcelor Mittal Eisenhüttenstadt GmbH	no	metal working	19.11.2014 08:45 am			http://www.arcelormittal-ehst.com	ArcelorMittal Eisenhüttenstadt GmbH Werkstr. 1 15890 Eisenhüttenstadt (03364) 37 0	2	101
AVA Velsen GmbH	yes	waste mgmt.	18.11.2014 09:15 am	27.11.14	09.12.14	http://www.ava-velsen.de/	AVA Velsen GmbH Alte Grube Velsen 16 D-66127 Saarbrücken Telefon: +49 (0) 68 98 946-0	1	16
AVEA Entsorgungsbetriebe GmbH & Co. KG	yes	waste mgmt.	18.11.2014 09:15 am	27.11.14	09.12.14	http://www.avea.info/	AVEA GmbH & Co. KG Im Eisholz 3 51373 Leverkusen Telefon: +49 / 214 / 86 68 - 0	1	12
AVG Köln mbH	yes	waste mgmt.	18.11.2014 09:15 am	27.11.14	09.12.14	http://www.avgkoeln.de/	AVG Köln mbH Geestemünder Straße 23 50735 Köln Tel.: 0221 7170 - 0	1	45
AWG Abfallwirtschaftsgesellschaft mbH Wuppertal	yes	waste mgmt.	18.11.2014 09:15 am	27.11.14	09.12.14	www.awg-wuppertal.de/	AWG Abfallwirtschaftsgesellschaft mbH Wuppertal Korzert 15 42349 Wuppertal +49 (0)202 - 4042 - 0	1	30
B+T Energie GmbH	yes	waste mgmt.	18.11.2014 09:15 am	27.11.14	09.12.14	http://www.bt-umwelt.de/	B+T Umwelt GmbH Ernst-Diegel-Straße 4 Industriepark Ost II 36304 Alsfeld/Germany	1	28
Basell Polyolefine GmbH	no	chemical	18.11.2014 09:15 am	27.11.14	09.12.14	http://www.lyondellbasell.com	LyondellBasell Industries Basell Polyolefine GmbH Brühler Straße 60 50389 Wesseling Tel.: 02236 72-0	2	118
BASF Schwarzheide GmbH	no	chemical	18.11.2014 09:15 am	27.11.14	09.12.14		BASF Schwarzheide GmbH Schipkauer Straße 1 01987 Schwarzheide Telefon +49 35752 60	1	122
BASF SE	no	chemical	18.11.14					4	948
Bayerische Elektrizitätswerke GmbH	yes	electricity generation	18.11.14			http://www.bew-augsburg.de	Bayerische Elektrizitätswerke GmbH ERSD-H-B Schaezlerstraße 3 86150 Augsburg	1	11
Bayernoil Raffineriegesellschaft mbH	no	chemical	18.11.2014 09:15 am	27.11.14	09.12.14	http://www.bayernoil.de	BAYERNOIL Raffineriegesellschaft mbH Postfach 12 52 93328 Neustadt Telefon: (0 84 57) 8 - 0	1	25
BEKW Bioenergiekraftwerk Emsland GmbH & Co. KG	yes	biomass	18.11.2014 09:15 am	27.11.14	09.12.14	http://www.bioenergie-emsland.de/	BEKW Bioenergiekraftwerk Emsland GmbH & Co. KG Neuerostrasse 5 49824 Emlichheim Telefon: 05943-98559-10	1	11
BinderHolz Deutschland GmbH	no	wood working	18.11.2014 09:15 am	27.11.14	09.12.14	http://www.binderholz.com/	Binderholz GmbH Holzindustrie Zillertalstraße 39 A-6263 Fügen/Zillertal fon +43.5288.601	1	15
Biomasse Heizkraftwerk Herbrechtingen GmbH	yes	biomass	18.11.2014 09:15 am	27.11.14	09.12.14	http://www.biohkw.de/	Biomasseheizkraftwerk Herbrechtingen GmbH Oskar-von-Miller-Weg 1 89542 Herbrechtingen Telefon: +49 (0)7324 / 9899-0	1	16
Biomasse HKW Siegerland GmbH & Co.KG	yes	biomass	18.11.2014 09:15 am	27.11.14	09.12.14	http://www.oekotech-energie.de/	Ökotech GmbH Christine-Englerth-Str. 4 45665 Recklinghausen Tel.: 0 23 61- 30 22 8-10	1	14

Source: German Federal Network Agency (Bundesnetzagentur), List of power plants, accessed July 16, 2014; pre-processed by the author according to the stated criteria before.
Notice: Further information, such as name and email address of contact person and details about phone calls, is available on request from the author of this thesis.

Appendix 21. (continuation) **List of survey participants**

Company name	"Electricity generation" as core competence	Details about main industry segment	Survey sent	Survey reminder 1	Survey reminder 2	Internet page	Address / Contact details	Number of power plants	Amount of net nominal capacity (in MW)
Biomasseheizkraftwerk Odenwald GmbH	yes	biomass	18.11.2014 09:15 am	27.11.14	09.12.14	http://www.awn-online.de/		1	28
Biomasse-Heizkraftwerk-Herbrechtingen GmbH	duplicate	duplicate	duplicate					1	14
BKD Biokraftwerk Delitzsch GmbH	yes	electricity generation	insolvent					1	20
Boehringer Ingelheim Pharma GmbH & Co. KG	no	pharmaceutical	19.11.2014 08:45 am	rejected (answer gmx mail)		https://www.boehringer-ingelheim.de/contact.html	Kontakt Ingelheim Boehringer Ingelheim Pharma GmbH & Co. KG Binger Straße 173 55216 Ingelheim am Rhein Telefon +49 6132 77 0	1	12
Borchers Biomassekraftwerk GmbH	yes	biomass	18.11.2014 09:15 am	27.11.14	09.12.14	http://www.borchers-entsorgung.de	Borchers Kreislaufwirtschaft GmbH Hansestr. 44 46325 Borken Telefon: 02861/9341-0	1	11
BP Europa SE	no	chemical	19.11.2014 08:45 am			http://www.bp.com/de_de/germany/ueber-bp/unsere-aktivitaeten/produktion/bp-lingen/kontakt.html	BP Europa SE BP Lingen Raffineriestraße 49808 Lingen	1	66
Braunschweiger Versorgungs-AG & Co. KG	yes	electricity generation	18.11.2014 09:15 am	27.11.14	09.12.14	http://www.bs-energy.de	BS|ENERGY Braunschweiger Versorgungs-AG & Co. KG Taubenstraße 7 38106 Braunschweig	4	162
Bremerhavener Entsorgungsgesellschaft mbH	yes	waste mgmt.	18.11.2014 09:15 am	27.11.14	09.12.14	http://www.beg-bhv.de/	Bremerhavener Entsorgungsgesellschaft mbH Zur Hexenbrücke 16 27570 Bremerhaven Telefon: (0471) 1 86-0	1	14
Buchmann GmbH	no	food	18.11.2014 09:15 am	27.11.14	09.12.14	http://www.buchmann-gmbh.de/de/	Buchmann GmbH Fleisch- und Wurstspezialitäten Kaufstrasse 6-8 88287 Grünkraut-Gullen Tel.: +49 (0) 7 51 - 7 60 50	1	28
Cargill Deutschland GmbH	no	food	19.11.2014 08:45 am			http://www.cargill.de/de/locations/krefeld/index.jsp	Cerestarstraße 2, 47809 Krefeld, Germany Phone:+49 2151 57501	3	58
CR3-Kaffeeveredelung M. Hermsen GmbH	no	food	18.11.2014 09:15 am	27.11.14	09.12.14		CR3-Kaffeeveredelung M. Hermsen GmbH Waterbergstraße 14 28237 Bremen	1	15
CropEnergies Bioethanol GmbH Zeitz	yes	biomass	18.11.2014 09:15 am	27.11.14	09.12.14	http://www.cropenergies.com/de/Unternehmen/Standorte/Zeitz/	CropEnergies AG Gottlieb-Daimler-Str. 12 68165 Mannheim Telefon: +49 621 71 41 90-00	1	18
Currenta GmbH & Co. OHG	no	chemical	18.11.2014 09:15 am	27.11.14	09.12.14	http://www.currenta.de/	Currenta GmbH & Co. OHG 51368 Leverkusen Tel.: +49 214 30 0	4	266
Daimler AG	no	automotive	18.11.14				Daimler AG 70546 Stuttgart Deutschland Tel. +49 711 17 0	3	125
Daimler AG / UPM GmbH	no	automotive	27.11.2014 1:00 pm				Daimler AG 70546 Stuttgart Deutschland Tel. +49 711 17 0	1	98
Danpower Energie Service GmbH	duplicate	duplicate	duplicate					1	20
Danpower GmbH	yes	electricity generation	18.11.2014 09:15 am	27.11.14	09.12.14	http://www.danpower-gruppe.de	Danpower GmbH Charlottenstr. 40 14467 Potsdam Telefon + 49 (331) 2 37 82 0	1	13
Delkeskamp Verpackungswerke GmbH	no	transportation	18.11.2014 09:15 am	27.11.14	09.12.14	www.delkeskamp.de	Delkeskamp Verpackungswerke GmbH Hauptstraße 15, 49638 Nortrup +49 (0) 54 36/51-0	1	18
Deutsche Gasrußwerke GmbH & Co. KG	no	chemical	18.11.2014 09:15 am	27.11.14	09.12.14	http://www.gasruss.de/	KG Deutsche Gasrußwerke GmbH & Co Weidenstr. 70 - 72 44147 Dortmund +49 231 8592 - 0	1	16
DK Recycling und Roheisen GmbH	no	chemical	18.11.2014 09:15 am	27.11.14	09.12.14	http://www.dk-duisburg.de/	DK Recycling und Roheisen GmbH Werthauser Straße 182 47053 Duisburg (Hochfeld) +49 (203) 6081 - 0	1	21
Donau-Wasserkraft AG	yes	electricity generation	18.11.2014 09:15 am	27.11.14	09.12.14	http://www.rmd.de/	Rhein-Main-Donau AG Blutenburgstraße 20 80636 München +49 89 99 222 - 0	6	270
Dow Deutschland Anlagengesellschaft mbH	no	chemical	18.11.2014 09:15 am	27.11.14	09.12.14	http://www.dow.com/de-de/deutschland/unternehmen/energie/integriertes-energiekonzept-stade	Dow Deutschland Anlagengesellschaft mbH Werk Stade Buetzflether Sand 9 21683 Stade Tel. +49 4146- 91 0	2	353
Dow Wolff Cellulosics GmbH	no	chemical	18.11.2014 09:15 am	27.11.14	09.12.14	http://www.dow.com/de-de/deutschland/standorte/dow-bomlitz	Dow Wolff Cellulosics GmbH August-Wolff-Straße 13 29699 Bomlitz Deutschland Tel. +49 (0) 5161 44 39 01	1	22
DREWAG Stadtwerke Dresden GmbH	yes	electricity generation	19.11.2014 08:45 am			http://www.drewag.de	DREWAG - Stadtwerke Dresden GmbH Abteilung Materialwirtschaft 01065 Dresden Tel.: (03 51) 8 60 89 70	1	250
DREWSEN SPEZIALPAPIERE GmbH & Co.KG	no	paper production	18.11.2014 09:15 am	27.11.14	09.12.14	http://www.drewsen.com/	DREWSEN SPEZIALPAPIERE GmbH & Co. KG Georg-Drewsen-Weg 2 D-29331 Lachendorf Telefon: +49 (0) 51 45 - 8 80	1	13

Source: German Federal Network Agency (Bundesnetzagentur), List of power plants, accessed July 16, 2014; pre-processed by the author according to the stated criteria before.
Notice: Further information, such as name and email address of contact person and details about phone calls, is available on request from the author of this thesis.

Appendix 21. (continuation) **List of survey participants**

Company name	"Electricity generation" as core competence	Details about main industry segment	Survey sent	Survey reminder 1	Survey reminder 2	Internet page	Address / Contact details	Number of power plants	Amount of net nominal capacity (in MW)
DS Smith Paper Deutschland GmbH	no	paper production	18.11.2014 09:15 am	27.11.14	09.12.14	http://www.dssmith.com/paper/about/paper-mills/aschaffenburg-de/	DS Smith Aschaffenburg Mill Weichertstraße 7 D-63741 Aschaffenburg	2	60
E.ON Kernkraft GmbH	yes	electricity generation	27.11.2014 1:00 pm			http://www.eon.com/de/ueber-uns/struktur/unternehmenssuche/eon-kernkraft-gmbh.html#Kontakt	E.ON Kernkraft GmbH Tresckowstraße 5 30457 Hannover	4	5.455
E.ON Kraftwerke GmbH	yes	electricity generation	27.11.2014 1:00 pm			http://www.eon.com/de/info-service/kontakt.html	E.ON Kraftwerke GmbH Tresckowstraße 5 30457 Hannover	50	9.788
EBS - Kraftwerks GmbH	no	waste mgmt.	19.11.2014 08:45 am			http://www.eew-energyfromwaste.com/de/unsere-standorte/knapsack.html		1	33
EEG-Anlagen < 10 MW	n/a	n/a	n/a	n/a	n/a	n/a		40	6.995
EEV BioEnergie GmbH & Co. KG	yes	biomass	18.11.2014 09:15 am	27.11.14	09.12.14	http://www.eev-ag.de/geschaeftsbereiche/biomasseheizkraftwerk-papenburg--a3/	30457 Hannover	1	20
EEW Energy from Waste Göppingen GmbH	yes	waste mgmt.	18.11.2014 09:15 am	27.11.14	09.12.14	http://www.eew-energyfromwaste.com/de/unsere-standorte/goeppingen.html	EEW Energy from Waste Göppingen GmbH	1	11
EEW Energy from Waste Großräschen GmbH	yes	waste mgmt.	18.11.2014 09:15 am	27.11.14	09.12.14	http://www.eew-energyfromwaste.com/de/unsere-standorte/grossraeschen.html	EEW Energy from Waste Großräschen GmbH	1	23
EEW Energy from Waste Hannover GmbH	yes	waste mgmt.	18.11.2014 09:25 am	27.11.14		#NAME?	EEW Energy from Waste Hannover GmbH Moorwaldweg 310 30659 Hannover T +49 5 11 33 63 97-0	1	23
EEW Energy from Waste Helmstedt GmbH	yes	waste mgmt.	18.11.2014 09:15 am	27.11.14	09.12.14	http://www.eew-energyfromwaste.com/de/unsere-standorte/helmstedt.html	EEW Energy from Waste Helmstedt GmbH TRV Buschhaus An der B244 38350 Helmstedt	1	38
EEW Energy from Waste Premnitz GmbH	yes	waste mgmt.	18.11.2014 09:15 am	27.11.14	09.12.14	http://www.eew-energyfromwaste.com/de/unsere-standorte/premnitz.html	EEW Energy from Waste Premnitz GmbH Dr. Herbert-Rein-Strasse 1 14727 Premnitz	1	15
EEW Energy from Waste Saarbrücken GmbH	yes	waste mgmt.	18.11.2014 09:15 am	27.11.14	09.12.14	http://www.eew-energyfromwaste.com/de/unsere-standorte/saarbruecken.html	EEW Energy from Waste Saarbrücken GmbH Dudweilerstraße 41 66111 Saarbrücken	3	40
EEW Energy from Waste Stapelfeld GmbH	yes	waste mgmt.	18.11.2014 09:20 am	27.11.14	09.12.14		EEW Energy from Waste Stapelfeld GmbH Ahrensburger Weg 4 22145 Stapelfeld T +49 40 6 75 76-0	1	16
Egger Kraftwerk Brilon GmbH	no	wood working	18.11.2014 09:15 am	27.11.14	09.12.14	http://www.egger.com/DE_de/werksleitung.htm	EGGER Holzwerkstoffe Brilon Gmb H & Co KG Im Kissen 19 59929 Brilon Thomas Abrell Werksleitung Logistik T +49 2961 770-0	2	32
EGK Entsorgungsgesellschaft Krefeld GmbH & Co.KG	yes	waste mgmt.	18.11.2014 09:15 am	27.11.14	09.12.14	http://www.egk.de/	EGK Entsorgungsgesellschaft Krefeld GmbH & Co. KG Parkstraße 234 47829 Krefeld Telefon: 02151/495-0	2	27
eins energie in sachsen GmbH & Co. KG	yes	electricity generation	18.11.2014 09:15 am	27.11.14	09.12.14	http://www.eins.de/ueber-eins/anlagen-und-netze/heizkraftwerk-chemnitz/	eins energie in sachsen GmbH & Co. KG Straße der Nationen 140 09113 Chemnitz	3	205
ENAG/Maingas Energieanlagen GmbH	yes	electricity generation	18.11.2014 09:15 am	27.11.14	09.12.14	http://www.emeg-eisenach.de	ENAG/Maingas Energieanlagen GmbH Adam- Opel- Straße 101 99817 Eisenach/ Thüringen	1	22
EnBW Energie Baden-Württemberg AG	yes	electricity generation	27.11.2014 1:00 pm			https://www.enbw.com	EnBW Energie Baden-Württemberg AG Durlacher Allee 93 76131 Karlsruhe	42	10.979
EnBW Klenk Holzenergie GmbH	yes	biomass	19.11.2014 08:45 am			www.klenk.com	Werk Oberrot / Zentrale Eugen-Klenk-Straße 2-4 D-74420 Oberrot Telefon: +49 (0)7977/72-0	1	19
EnBW Propower GmbH	yes	electricity generation	19.11.2014 08:45 am			http://www.emas.de/fileadmin/user_upload/umwelterklaerungen/2011/DE-148-000032_EnBW-Propower-GmbH_2011.pdf	EnBW Propower GmbH Oderlandstraße 109 15890 Eisenhüttenstadt	1	24

Source: German Federal Network Agency (Bundesnetzagentur), List of power plants, accessed July 16, 2014; pre-processed by the author according to the stated criteria before.
Notice: Further information, such as name and email address of contact person and details about phone calls, is available on request from the author of this thesis.

Appendix 21. (continuation) **List of survey participants**

Company name	"Electricity generation" as core competence	Details about main industry segment	Survey sent	Survey reminder 1	Survey reminder 2	Internet page	Address / Contact details	Number of power plants	Amount of net nominal capacity (in MW)
Energie SaarLorLux AG	yes	electricity generation	18.11.2014 09:15 am	27.11.14	09.12.14	https://www.energie-saarlorlux.com/	Energie SaarLorLux AG Richard-Wagner-Straße 14-16 66111 Saarbrücken Marktprozesse Tel.: (06 81) 5 87-47 55	1	75
Energie- und Medienversorgung Sandhofer Straße GmbH & Co. KG	yes	electricity generation	18.11.2014 09:15 am	27.11.14	09.12.14	http://www.twl.de/de/Unternehmen/Technische-Werke-Ludwigshafen-AG/Tochterunternehmen/Voller_Energie_-_Unsere_Toechter.html	Technische Werke Ludwigshafen AG Industriestraße 3 67063 Ludwigshafen	1	17
Energie- und Medienversorgung Schwarza GmbH	yes	electricity generation	18.11.2014 09:15 am	27.11.14	09.12.14	http://www.ems-schwarza.de/	Energie- und Medienversorgung Schwarza GmbH Breitscheidstraße 160 07407 Rudolstadt Tel (03672) 48900	1	27
Energie und Wasser Potsdam GmbH	yes	electricity generation	18.11.2014 09:15 am	27.11.14	09.12.14	https://www.swp-potsdam.de	Energie und Wasser Potsdam GmbH EWP-Verwaltungsgebäude Steinstraße 101 14480 Potsdam	1	82
Energie- und Wasserversorgung Bonn/Rhein-Sieg GmbH	yes	electricity generation	19.11.14			http://www.stadtwerke-bonn.de/energieundwasser.html	Energie- und Wasserversorgung Bonn/Rhein-Sieg GmbH (SWB Energie und Wasser) Welschnonnenstr. 4 53111 Bonn Tel. 0228 - 711 1	2	107
EnergieDienst AG	yes	electricity generation	18.11.2014 09:15 am	27.11.14	09.12.14	http://www.energiedienst.de/	Thomas Zirowsky Standort: Rheinfelden Tel: +49 7623 92-3431	2	85
Energiedienst Holding AG	yes	electricity generation	18.11.2014 09:15 am	27.11.14	09.12.14	http://www.energiedienst.de/	Energiedienst Holding AG Baslerstrasse 44 CH-5080 Laufenburg	1	104
Energieerzeugungsgesellschaft Greifswald GmbH	yes	electricity generation	18.11.2014 09:15 am	27.11.14	09.12.14	http://www.sw-greifswald.de	Stadtwerke Greifswald GmbH Gützkower Landstraße 19–21 17489 Greifswald Telefon 03834 53-0 Eckhard Schult Tel.: 03834-532120	1	15
Energieservice Westfalen Weser GmbH	yes	electricity generation	18.11.2014 09:15 am	27.11.14	09.12.14	http://energieservice-ww.com/	Energieservice Westfalen Weser GmbH Bahnhofstraße 40 32278 Kirchlengern	1	202
Energieversorgung Gera GmbH	yes	electricity generation	18.11.2014 09:15 am	27.11.14	09.12.14	http://www.energieversorgung-gera.de/	Energieversorgung Gera GmbH De-Smit-Straße 18 D-07545 Gera Tel.: 0365 856-0 Beschaffung Jens Penndorf 0365 856-1111	1	74
Energieversorgung Oberhausen AG	yes	electricity generation	18.11.2014 09:15 am	27.11.14	09.12.14	http://www.evo-energie.de/	Energieversorgung Oberhausen AG Einkauf und Materialwirtschaft Danziger Straße 31 46045 Oberhausen T 0208 835-2236	2	48
Energieversorgung Offenbach AG	yes	electricity generation	18.11.2014 09:15 am	27.11.14	09.12.14	https://www.evo-ag.de/	Energieversorgung Offenbach AG (EVO) Andréstr. 71 63067 Offenbach Klaus Szukala Leiter Einkauf und Materialwirtschaft Tel. 069/8060-1630	2	64
Energieversorgung Schwerin GmbH & Co. Erzeugung KG	yes	electricity generation	18.11.2014 09:15 am	27.11.14	09.12.14	http://www.stadtwerke-schwerin.de	Stadtwerke-Schwerin Eckdrift 43 - 45 19061 Schwerin Telefon: 0385 633-0	2	68
Energieversorgungscenter Dresden-Wilschdorf GmbH & Co. KG	yes	electricity generation	18.11.2014 09:15 am	27.11.14	09.12.14	http://www.bhkw-infozentrum.de	BHKW-Infozentrum GbR Rauentaler Straße 22/1 76437 Rastatt Gesellschafter: Markus Gailfuß, Erich Gailfuß	1	34
Enertec Hameln GmbH	yes	waste mgmt.	18.11.2014 09:15 am	27.11.14	09.12.14	http://www.enertec-hameln.de/	Enertec Hameln GmbH Heinrich-Schoormann-Weg 1 31789 Hameln Werner Hamschmidt T 0521 3398-106	2	32
ENERTRAG Aktiengesellschaft	yes	waste mgmt.	18.11.2014 09:15 am	27.11.14	09.12.14	https://www.enertrag.com/	ENERTRAG Gut Dauerthal 17291 Dauerthal	1	20
Entsorgungsgesellschaft Mainz mbH	yes	waste mgmt.	18.11.2014 09:15 am	27.11.14	09.12.14	http://www.mhkw-mainz.de/	Entsorgungsgesellschaft Mainz mbH Kraftwerkallee 1 55120 Mainz	1	16
envia THERM GmbH	yes	waste mgmt.	18.11.14			https://www.envia-therm.de/	envia THERM GmbH Magdeburger Straße 51 06112 Halle	5	335
Erlanger Stadtwerke AG	yes	electricity generation	18.11.2014 09:15 am	27.11.14	09.12.14	http://www.estw.de/	ESTW - Erlanger Stadtwerke AG Äußere Brucker Straße 33 D - 91052 Erlangen Telefon: 09131 823-4141	2	39
ESWE BioEnergie GmH	yes	biomass	18.11.2014 09:15 am	27.11.14	09.12.14	http://www.eswe-bioenergie.de	ESWE BioEnergie GmbH -Betriebsbüro BioEnergie- Claudia Ruf / Hülya Saba Deponiestraße14, 65205 Wiesbaden Telefon: 0611 780-3275	1	11

Source: German Federal Network Agency (Bundesnetzagentur), List of power plants, accessed July 16, 2014; pre-processed by the author according to the stated criteria before.
Notice: Further information, such as name and email address of contact person and details about phone calls, is available on request from the author of this thesis.

Appendix 21. (continuation) **List of survey participants**

Company name	"Electricity generation" as core competence	Details about main industry segment	Survey sent	Survey reminder 1	Survey reminder 2	Internet page	Address / Contact details	Number of power plants	Amount of net nominal capacity (in MW)
Eurowatt Spitzenkraft GmbH	yes	electricity generation	18.11.2014 09:15 am	27.11.14	09.12.14	eurowatt.de	Eurowatt Spitzenkraft GmbH Ruselbergstr. 87 94469 Deggendorf Tel +49 991 29061-0	1	19
EVH GmbH	yes	electricity generation	18.11.2014 09:15 am	27.11.14	09.12.14	http://www.evh.de	EVH GmbH Bornknechtstraße 5 06108 Halle (Saale) Telefon: (0345) 5 81 - 0	1	97
Evonik Degussa GmbH	no	chemical	19.11.2014 08:45 am			http://corporate.evonik.com/en/company/locations/europe/germany/rheinfelden/Pages/default.aspx	Evonik Industries AG Untere Kanalstraße 3 79618 Rheinfelden	1	16
Evonik Industries AG (Werk Worms)	no	chemical	19.11.2014 08:45 am			http://corporate.evonik.de/de/unternehmen/standorte/europa/deutschland/worms/Pages/default.aspx	Standortkommunikation Gabriele Engert +49 6241 402-7055	1	12
EVZA Energie- und Verwertungszentrale GmbH, Anhalt	yes	electricity generation	18.11.2014 09:15 am	27.11.14	09.12.14	http://www.evza.de/	EVZA Energie- und Verwertungszentrale GmbH, Anhalt Butterwecker Weg 6 D-39418 Staßfurt Telefon: +49(0)39 25/ 32 09 - 1 10	1	24
Fernwärme Ulm GmbH	yes	electricity generation	18.11.2014 09:15 am	27.11.14	09.12.14	http://www.f-u-g.com	Fernwärme Ulm GmbH Magirusstrasse 21 89077 Ulm Telefon: 0731/3992-0	1	21
Flughafen München GmbH	no	airport	18.11.2014 09:15 am	27.11.14	09.12.14	http://www.munich-airport.de	Flughafen München GmbHNordallee 25 85356 München-Flughafen	1	11
Freiberger Erdgas GmbH	yes	electricity generation	18.11.2014 09:15 am	27.11.14	09.12.14	http://www.stadtwerke-freiberg.de/	Stadtwerke FREIBERG AG Poststraße 5 09599 Freiberg Tel.: 03731 30 94-140	1	13
FS-Karton GmbH	yes	electricity generation	18.11.2014 09:15 am	27.11.14	09.12.14	http://www.mm-karton.com/	FS-Karton GmbH Düsseldorfer Straße 182-184 41460 Neuss Deutschland Tel: +49 2131 237-0	1	19
GDF SUEZ E&P DEUTSCHLAND GMBH	yes	electricity generation	19.11.2014 08:45 am			http://www.gdfsuezep.de/service/kontakt/	GDF SUEZ E&P Deutschland GmbH Waldstraße 39 49808 Lingen (Ems)	1	11
GDF SUEZ Energie Deutschland AG	yes	electricity generation	19.11.2014 08:45 am			https://www.gdfsuez-energie.de/de/kontakt	GDF SUEZ Energie Deutschland AG Friedrichstraße 200 10117 Berlin 030/726153-500	5	995
Gemeinschaft nach Bruchteilen der Saarstahl AG (SAG) und Saarschmiede GmbH Freiformschmiede (SSF)	no	metal working	18.11.2014 09:15 am	27.11.14	09.12.14	http://www.saarstahl.de/kontakte.html	SHS SERVICES GmbH Bismarckstraße 145 66333 Völklingen Tel.: +49 (0) 68 98 10 48 66	1	283
Gemeinschaftskraftwerk Irsching GmbH	yes	electricity generation	27.11.2014 1:00 pm			http://www.eon.com/de/ueber-uns/struktur/asset-finder/irsching.html	Kraftwerk Irsching (Eon) Paarstraße 30 85088 Vohburg T +49 8457-753101	1	846
Gemeinschaftskraftwerk Kiel GmbH	yes	electricity generation	18.11.2014 09:15 am	27.11.14	09.12.14	http://www.gkk-kiel.de/	Gemeinschaftskraftwerk Kiel GmbH Hasselfelde 40 24149 Kiel Telefon: 0431 2002-0	1	323
Gemeinschaftskraftwerk Veltheim GmbH	yes	electricity generation	18.11.2014 09:15 am	27.11.14	09.12.14	http://www.gk-veltheim.de/	GEMEINSCHAFTSKRAFTWERK VELTHEIM GMBH Möllberger Straße 387 D - 32457 Porta Westfalica	2	368
Geno Bioenergie Leasingfonds Erste GmbH & Co. KG	yes	biomass	18.11.2014 09:15 am	27.11.14	09.12.14	http://nawaro.ag/de/unternehmen/projekte/bioenergiepark-klarsee/	NAWARO® BioEnergie Park „Klarsee“ GmbH Ernst-Röwer-Ring 2 17329 Krackow Fon + 49 (0)39 746 – 26 51 74	1	18
Georg-August-Universität Göttingen Stiftung Öffentlichen Rechts	no	education	18.11.2014 02:54 pm	27.11.14		https://www.uni-goettingen.de/de/technisches-geb%C3%A4udemanagement-gm-3/14125.html	Georg-August-Universität Göttingen Wilhelmsplatz 1 37073 Göttingen Tel. +49 (0)551 / 39-0	1	19
GHP Glunz Holzwerkstoffproduktion GmbH	no	wood working	18.11.2014 09:15 am	27.11.14	09.12.14	http://www.glunz.de	GHP Glunz Holzwerkstoffproduktion GmbH Werk Horn - Bad Meinberg Bahnhofstraße 57 32805 Horn - Bad Meinberg +49(0) 5234.848 0	1	20
GKS Gemeinschaftskrafterk Schweinfurt GmbH	yes	electricity generation	18.11.2014 09:15 am	27.11.14	09.12.14	http://www.gks-schweinfurt.de/	Gemeinschaftskraftwerk Schweinfurt GmbH Hafenstraße 30 D - 97424 Schweinfurt	1	24
GMVA Gemeinschafts-Müll-Verbrennungsanlage Niederrhein GmbH	yes	waste mgmt.	18.11.2014 09:15 am	27.11.14	09.12.14	http://www.gmva.de	Gemeinschafts-Müllverbrennungsanlage Niederrhein GmbH Liricher Straße 121 46049 Oberhausen Telefon: +49 (0)208 8594-0	2	62
Grace GmbH & Co. KG	no	chemical	18.11.2014 09:15 am	27.11.14	09.12.14	www.*gracedavison*.com	Grace GmbH & Co. KG In der Hollerhecke 1 67545 Worms	1	12
Grosskraftwerk Mannheim AG	yes	electricity generation	18.11.2014 09:15 am	27.11.14	09.12.14	http://www.gkm.de/	Grosskraftwerk Mannheim Aktiengesellschaft Marguerrestraße 1 68199 Mannheim Tel: (06 21) 8 68-0	4	1.318
HBB Heizkraftwerk Bauernfeind Betreibergesellschaft mbh	yes	biomass	18.11.2014 09:15 am	27.11.14	09.12.14	BAUERNFEIND.DE	HBB Heizkraftwerk Bauernfeind Betreibergesellschaft mbH Rosenheimer Straße 37 83064 Raubling Telefon:08035 9020	1	24

Source: German Federal Network Agency (Bundesnetzagentur), List of power plants, accessed July 16, 2014; pre-processed by the author according to the stated criteria before.
Notice: Further information, such as name and email address of contact person and details about phone calls, is available on request from the author of this thesis.

Appendix 21. (continuation) **List of survey participants**

Company name	"Electricity generation" as core competence	Details about main industry segment	Survey sent	Survey reminder 1	Survey reminder 2	Internet page	Address / Contact details	Number of power plants	Amount of net nominal capacity (in MW)
HEAG Südhessische Energie AG (HSE)	yes	electricity generation	18.11.2014 09:15 am	27.11.14	09.12.14	http://www.hse.ag/	HEAG Südhessische Energie AG (HSE) Zentraleinkauf (P200) Dornheimer Weg 24 64293 Darmstadt	1	95
Heizkraftwerk Halle-Trotha GmbH	yes	electricity generation	18.11.2014 09:15 am	27.11.14	09.12.14	http://www.stadtwerke-halle.de/SWH/Gemeinsames-Untermenue/Kraftwerke/	Heizkraftwerk Halle-Trotha GmbH Bornknechtstraße 5 06108 Halle (Saale) Telefon: (0345) 5 81 - 0	1	54
Heizkraftwerk Pforzheim GmbH	yes	electricity generation	18.11.2014 09:15 am	27.11.14	09.12.14	https://www.heizkraftwerk-pforzheim.de	Heizkraftwerk Pforzheim GmbH Sandweg 22 75179 Pforzheim	4	92
Henkel AG & Co.KGaA	no	chemical	19.11.2014 08:45 am	rejected (answer gmx mail)		www.henkel.de	Henkel AG & Co. KGaA Henkelstraße 67 40589 Düsseldorf Deutschland	1	84
HKW Heizkraftwerksgesellschaft Cottbus mbH	yes	electricity generation	18.11.2014 09:15 am	27.11.14	09.12.14	http://www.stadtwerke-cottbus.de	Stadtwerke Cottbus GmbH Karl - Liebknecht - Straße 130 03046 Cottbus Tel.: 0355 351 - 0	1	74
Hummel Energiesysteme Neuss I	yes	electricity generation	18.11.2014 09:15 am	27.11.14	09.12.14	http://www.hummelenergie.de/	HummelEnergie Holding GmbH Duisburger Straße 6 D-41460 Neuss Fon: +49 (0)2131/73999-00	1	12
Hüttenwerke Krupp Mannesmann GmbH	no	metal working	18.11.2014 09:15 am	27.11.14	09.12.14	http://www.hkm.de/	Hüttenwerke Krupp Mannesmann GmbH 47259 Duisburg Telefon: +49 (0)203-999-01	2	606
IHKW Industrieheizkraftwerk Andernach GmbH	yes	electricity generation	18.11.2014 09:20 am	27.11.14	09.12.14	http://www.eew-energyfromwaste.com/de/unsere-standorte/andernach.html	IHKW Andernach GmbH Koblenzer Straße 141 56626 Andernach T +49 26 32 4 98 59-0	1	13
Industriekraftwerk Breuberg GmbH	yes	chemical	18.11.2014 09:15 am	27.11.14	09.12.14	pirelli.com	Industriekraftwerk Breuberg GmbH Höchster Str. 48, 64747 Sandbach Tel: 06163 712735	1	11
Industriekraftwerk Greifswald GmbH	yes	electricity generation	27.11.2014 1:00 pm			https://www.dvgw-sc.de	Industriekraftwerk Greifswald GmbH Friedrich-Ebert-Straße 160 34119 Kassel	1	38
Ineos Manufacturing Deutschland GmbH	no	chemical	18.11.2014 09:15 am	27.11.14	09.12.14	http://www.ineoskoeln.de/	INEOS Köln GmbH Alte Straße 201 50769 Köln	4	70
Infracor GmbH	yes	electricity generation	18.11.2014 09:15 am	27.11.14	09.12.14	http://www.infracor.de	Infracor GmbH (vertreten durch die Geschäftsführung) Paul-Baumann-Straße 1 45772 Marl Dr. Hermann-Josef Korte +49 2365 49-5339	6	435
InfraLeuna GmbH	no	chemical	18.11.2014 09:15 am	27.11.14	09.12.14	http://www.infraleuna.de	InfraLeuna GmbH Am Haupttor, Bau 4310 06237 Leuna	5	141
InfraServ GmbH & Co. Gendorf KG	no	chemical	18.11.2014 09:15 am	27.11.14	09.12.14	http://www.infraserv.gendorf.de/	InfraServ GmbH & Co. Gendorf KG Industriepark Werk Gendorf	1	49
Infraserv GmbH & Co. Höchst KG	no	chemical	18.11.2014 09:15 am	27.11.14	09.12.14	http://www.infraserv.com/de/index.jsp	Infraserv GmbH & Co. Höchst KG Industriepark Höchst 65926 Frankfurt am Main Telefon +49 69 305-6767	3	249
InfraServ GmbH & Co. Wiesbaden KG	no	chemical	18.11.2014 09:15 am	27.11.14	09.12.14	http://www.infraserv-wi.de/	InfraServ GmbH & Co. Wiesbaden KG Kasteler Straße 45 65203 Wiesbaden Telefon: 0611-962-01	1	25
Innwerk AG	yes	electricity generation	27.11.2014 1:00 pm			http://www.verbund.com	Innwerk AG Schulstr. 2 84533 Stammham	8	351
K+S AG	yes	electricity generation	18.11.2014 09:15 am	27.11.14	09.12.14	www.k-plus-s.com	K+S Aktiengesellschaft Bertha-von-Suttner-Str. 7 34131 Kassel Tel.: +49 561 9301 0	6	266
Kernkraftwerk Gundremmingen GmbH (KGG)	yes	electricity generation	18.11.14			http://www.kkw-gundremmingen.de/	Kernkraftwerke Gundremmingen GmbH Dr.-August-Weckesser-Straße 1 89355 Gundremmingen Te:08224 782231	2	2.572
Kernkraftwerke Lippe-Ems GmbH (KLE)	yes	electricity generation	18.11.14			n/a	Kernkraftwerke Lippe-Ems GmbH Am Hilgenberg 1 49811 Lingen (Ems) Tel:0231 4382365	1	1.329
KGW - Kraftwerk Grenzach-Wyhlen GmbH	yes	electricity generation	18.11.2014 09:15 am	27.11.14	09.12.14	http://www.energiedienst.de/	KGW - Kraftwerk Grenzach- Wyhlen GmbH Denisstr. 2 80335 München	1	40
Klausner Holz Thüringen GmbH	no	wood working	18.11.2014 09:15 am	27.11.14	09.12.14	http://www.klausner-group.com/	Klausner Trading International GmbH Zentrale/Vertriebsbüro Bahnhofstraße 13 6372 Oberndorf in Tirol Österreich / Austria	1	13
Koehler Energie GmbH	no	paper production	18.11.2014 09:15 am	27.11.14	09.12.14	http://www.koehlerpaper.com	Koehler Renewable Energy GmbH Hauptstraße 2-4 77704 Oberkirch Tel +49 (0) 7802 81-0	1	19
Kraftwerk Dessau GmbH	yes	electricity generation	18.11.2014 09:15 am	27.11.14	09.12.14	https://www.dvv-dessau.de/v1/213-0-Kraftwerk+Dessau+GmbH.html	Dessauer Versorgungs- und Verkehrsgesellschaft mbH Albrechtstraße 48 06844 Dessau-Roßlau Tel.: 0340 899 0	1	49

Source: German Federal Network Agency (Bundesnetzagentur), List of power plants, accessed July 16, 2014; pre-processed by the author according to the stated criteria before.
Notice: Further information, such as name and email address of contact person and details about phone calls, is available on request from the author of this thesis.

Appendix 21. (continuation) **List of survey participants**

Company name	"Electricity generation" as core competence	Details about main industry segment	Survey sent	Survey reminder 1	Survey reminder 2	Internet page	Address / Contact details	Number of power plants	Amount of net nominal capacity (in MW)
Kraftwerk Obernburg GmbH	yes	electricity generation	18.11.2014 09:15 am	27.11.14	09.12.14	http://www.mainsite.de	Mainsite GmbH & Co.KG Industrie Center Obernburg 63784 Obernburg	2	100
Kraftwerk Schwedt GmbH & Co. KG	yes	waste mgmt.	18.11.2014 09:15 am	27.11.14	09.12.14	http://www.eew-energyfromwaste.com/de/unsere-standorte/schwedt.html	Kraftwerk Schwedt GmbH & Co. KG Kuhheide 34 16303 Schwedt Markus Neumann Vertrieb Ost Schöninger Str. 2-3 38350 Helmstedt T +49 53 51 18-23 41	1	29
Kraftwerke Mainz-Wiesbaden AG	yes	electricity generation	18.11.2014 09:15 am	27.11.14	09.12.14	http://www.kmw-ag.de/	Kraftwerke Mainz-Wiesbaden AG Kraftwerkallee 1 55120 Mainz Telefon: +49 (0) 61 31.9 76 - 0	1	398
Kreis Weseler Abfallgesellschaft mbH & Co. KG (KWA)	yes	waste mgmt.	18.11.2014 09:15 am	27.11.14	09.12.14	http://www.aez-asdonkshof.de	Kreis Weseler Abfall- gesellschaft mbH & Co. KG Abfallentsorgungszentrum (AEZ) Asdonkshof Graftstr. 25 47475 Kamp-Lintfort Tel. 02842 / 940 - 0	1	16
Kronoply GmbH	no	wood working	18.11.2014 09:15 am	25.11.2014 10:28 am Weblink1 (gmx-mail)	09.12.14	http://www.kronoply.com	Kronoply GmbH Wittstocker Chaussee 1 16909 Heiligengrabe	1	19
Kübler & Niethammer Papierfabrik Kriebstein AG	no	paper production	18.11.2014 09:15 am	27.11.14	09.12.14	http://www.k-n-paper.de	Kübler & Niethammer Papierfabrik Kriebstein AG Bauhofstraße 1 OT Kriebethal 09648 Kriebstein	1	13
KWG-Kraftwerksgesellschaft Staßfurt mbH	yes	waste mgmt.	18.11.2014 09:15 am	27.11.14	09.12.14	http://www.evza.de/	KWG-KW-Gesellschaft Staßfurt GmbH Athenslebener Weg 57 39418 Staßfurt	1	132
Lister- und Lennekraftwerke GmbH	yes	electricity generation	18.11.2014 09:15 am	27.11.14	09.12.14	https://www.llk.de/	Lister- und Lennekraftwerke GmbH In der Wüste 8 57462 Olpe Fon: 02761 896-0	1	15
Mainova AG	yes	electricity generation	18.11.2014 09:15 am	27.11.14	09.12.14	https://www.mainova.de/	Mainova AG Solmsstraße 38 60623 Frankfurt am Main	9	453
Mark-E AG	yes	electricity generation	18.11.2014 09:15 am	27.11.14	09.12.14	http://www.mark-e.de	Mark-E Platz der Impulse 1 58093 Hagen Tel.: 02331. 123-0	5	904
Mark-E AG / Statkraft Markets GmbH	yes	electricity generation	18.11.2014 09:20 am	27.11.14	09.12.14	http://www.mark-e.de	Mark-E Aktiengesellschaft Cuno-Heizkraftwerk Herdecke Wetterstraße 111 58313 Herdecke	1	417
Metsä Tissue GmbH Werk Düren	no	paper production	18.11.2014 09:15 am	27.11.14	09.12.14	http://www.metsatissue.de	Metsä Tissue Werk Düren Veldener Straße 121-131 D-52349 Düren	1	14
MHB Hamm Betriebsführungsgesellschaft mbH	yes	waste mgmt.	18.11.2014 09:15 am	27.11.14	09.12.14	http://www.mva-hamm.de/	MVA Hamm Betreiber-GmbH Am Lausbach 2 59075 Hamm 02381 / 4835-91	1	15
Michelin Reifenwerke AG & Co. KGaA Standort Bad Kreuznach	no	tire production	18.11.2014 09:15 am	27.11.14	09.12.14	http://www.michelin.de/unternehmen/bad-kreuznach	Kontakt Michelin Reifenwerke AG & Co. KGaA Werk Bad Kreuznach Michelinstraße 1 55543 Bad Kreuznach Telefon: 0671 855-0	1	11
Mineraloelraffinerie Oberrhein GmbH & Co. KG	no	chemical	18.11.2014 09:15 am	27.11.14	09.12.14	www.miro-ka.de	MiRO Mineraloelraffinerie Oberrhein GmbH & Co. KG Nördliche Raffineriestr. 1 76187 Karlsruhe Tel. 0721 / 958-01	2	70
Mitteldeutsche Braunkohlengesellschaft mbH	yes	electricity generation	18.11.2014 09:15 am	27.11.14	09.12.14	http://www.mibrag.de	Mitteldeutsche Braunkohlengesellschaft mbH Glück-Auf-Straße 1 D-06711 Zeitz	2	98
Mohn Media Mohndruck GmbH	no	paper production	18.11.2014 09:15 am	27.11.14	09.12.14	http://www.mohnmedia.de	Mohn Media Mohndruck GmbH Carl-Bertelsmann-Str. 161M 33311 Gütersloh	1	22
Molkerei MEGGLE Wasserburg GmbH & Co. KG	no	food	18.11.2014 09:15 am	27.11.14	09.12.14	http://www.meggle.com/de/unternehmen/standorte/deutschland-wasserburg/	MEGGLE AG Megglestraße 6-12 83512 Wasserburg am Inn +49 (0) 80 71-73-0	1	13
Moritz J. Weig GmbH & Co KG	no	paper production	18.11.2014 09:15 am	27.11.14	09.12.14	http://www.weig-karton.de	Moritz J. Weig GmbH & Co. KG Polcher Straße 113 56727 Mayen · Germany Phone +49 (0) 2651 / 84 - 0	1	42
Müllheizkraftwerk Kassel GmbH	yes	waste mgmt.	18.11.2014 09:15 am	27.11.14	09.12.14	www.mhkw-kassel.de	Müllheizkraftwerk Kassel GmbH Königstor 3-13 34117 Kassel Telefon: 0561 / 782 0	1	15

Source: German Federal Network Agency (Bundesnetzagentur), List of power plants, accessed July 16, 2014; pre-processed by the author according to the stated criteria before.
Notice: Further information, such as name and email address of contact person and details about phone calls, is available on request from the author of this thesis.

Appendix 21. (continuation) **List of survey participants**

Company name	"Electricity generation" as core competence	Details about main industry segment	Survey sent	Survey reminder 1	Survey reminder 2	Internet page	Address / Contact details	Number of power plants	Amount of net nominal capacity (in MW)
Müllheizkraftwerk Rothensee GmbH	yes	waste mgmt.	18.11.2014 09:15 am	27.11.14	09.12.14	http://www.mhkw-rothensee.de	Müllheizkraftwerk Rothensee GmbH Kraftwerk-Privatweg 7 39126 Magdeburg Telefon:0391 5872534	2	58
MVA Bielefeld-Herford GmbH	yes	waste mgmt.	18.11.2014 09:15 am	27.11.14	09.12.14	http://www.mva-bielefeld.de/	MVA Bielefeld-Herford GmbH Schelpmilser Weg 30 33609 Bielefeld	1	34
MVB Müllverwertung Borsigstraße GmbH	yes	waste mgmt.	18.11.2014 09:15 am	27.11.14	09.12.14	http://www.mvb-hh.de/	Müllverwertung Borsigstraße GmbH Borsigstraße 6 22113 Hamburg Tel.: 040 / 73189-0	1	20
MVR Müllverwertung Rugenberger Damm GmbH & Co. KG	yes	waste mgmt.	18.11.2014 09:15 am	27.11.14	09.12.14	http://www.mvr-hh.de	MVR Müllverwertung Rugenberger Damm GmbH & Co. KG Rugenberger Damm 1 21129 Hamburg Telefon: (040) 74 186-100	1	24
MVV Energie AG	yes	electricity generation	18.11.2014 09:15 am	27.11.14	09.12.14	https://www.mvv-energie.de/de/	MVV Energie AG Kommunikation und Marke Luisenring 49 68159 Mannheim	8	127
N-ERGIE AG	yes	electricity generation	18.11.2014 09:15 am	27.11.14	09.12.14	https://www.n-ergie.de/	N-ERGIE Aktiengesellschaft 90338 Nürnberg E-Mail: dialog@n-ergie.de	3	168
Neubrandenburger Stadtwerke GmbH / VASA Kraftwerkepool GmbH und Co. KG	yes	electricity generation	18.11.2014 09:15 am	27.11.14	09.12.14	http://www.neu-sw.de/	Neubrandenburger Stadtwerke GmbH John-Schehr-Straße 1 17033 Neubrandenburg	1	75
Nicht-EEG-Anlagen < 10 MW	n/a	n/a	n/a	n/a	n/a	n/a		12	3.608
Obere Donau Kraftwerke AG	yes	electricity generation	18.11.14			http://www.bew-augsburg.de/CBP/Wasserkraft/Daten/ODK.asp	Obere Donau Kraftwerk AG Römerstraße 1 89415 Lauingen	1	10
Ökotech Ingenieurgesellschaft mbh	yes	biomass	18.11.2014 09:20 am	27.11.14	09.12.14	http://www.oekotech-energie.de/re.html	Ökotech GmbH Christine-Englerth-Str. 4 45665 Recklinghausen Tel.: 0 23 61- 30 22 8-10	1	14
Oxea GmbH	no	chemical	18.11.2014 09:15 am	27.11.14	09.12.14	http://www.oxea-chemicals.com/de/	OXEA GmbH Otto-Roelen-Str. 3 Werk Ruhrchemie Oberhausen 46147 Deutschland	1	38
Palm Power GmbH & Co. KG	no	paper production	18.11.2014 09:15 am	27.11.14	09.12.14	http://www.papierfabrik-palm.de/de/Kontakt/-palm.de	Papierfabrik Palm GmbH & Co. KG Neukochen 10 73432 Aalen Deutschland	2	113
Papier- u. Kartonfabrik Varel GmbH & Co. KG	no	paper production	18.11.2014 09:15 am	27.11.14	09.12.14	http://www.pkvarel.de/	Papier- u. Kartonfabrik Varel GmbH & Co. KG Dangaster Straße 38 D 26316 Varel Telefon: +49 [4451] 138 - 0	1	58
Papierfabrik Adolf Jass Schwarza GmbH	no	paper production	18.11.2014 09:15 am	27.11.14	09.12.14	http://www.jass.de/	Papierfabrik Adolf Jass GmbH & Co. KG Hermann-Muth-Straße 6 36039 Fulda Telefon: +49 (0661) 1 06-0	1	26
PCK Raffinerie GmbH	no	chemical	18.11.2014 09:15 am	27.11.14	09.12.14	http://www.pck.de/	PCK Raffinerie GmbH Passower Chaussee 111 16303 Schwedt/Oder T. +49 3332-46 0	5	334
Peissenberger Kraftwerksgesellschaft mbH Kraftwerk Hausham	yes	electricity generation	18.11.14			http://www.pkg-peissenberg.de/	Peissenberger Kraftwerks Gesellschaft mbH Stadelbachstr. 4a 82380 Peissenberg Telefon 08803 / 496 - 62	4	93
Pfeifer & Langen Kommanditgesellschaft	no	food	18.11.2014 09:15 am	27.11.14	09.12.14	www.pfeifer-langen.de/	Pfeifer & Langen GmbH & Co. KG Aachener Straße 1042 a 50858 Köln	5	81
Pfleiderer Baruth GmbH	no	wood working	18.11.2014 09:15 am	27.11.14	09.12.14	https://www.pfleiderer.com/	Pfleiderer Holzwerkstoffe GmbH Ingolstädter Str. 51 D-92318 Neumarkt	1	16
Pfleiderer Gütersloh GmbH	no	wood working	18.11.2014 09:25 am	27.11.14		https://www.pfleiderer.com/	Pfleiderer Holzwerkstoffe GmbH Ingolstädter Str. 51 D-92318 Neumarkt	1	12
Pfleiderer Neumarkt GmbH	no	wood working	18.11.2014 09:20 am	27.11.14	09.12.14	https://www.pfleiderer.com/	Pfleiderer Holzwerkstoffe GmbH Ingolstädter Str. 51 D-92318 Neumarkt	1	16
PN Biomasseheizkraftwerk Emlichheim GmbH & Co. KG	yes	biomass	insolvent					1	20
Raffinerie Heide GmbH	no	chemical	18.11.2014 09:15 am	27.11.14	09.12.14		Raffinerie Heide GmbH Meldorfer Straße 43, 25770 Hemmingstedt, Germany Tel. +49 (0)481/693-0	1	45
RAG Anthrazit Ibbenbüren GmbH	yes	electricity generation	18.11.2014 09:15 am	27.11.14	09.12.14	http://www.rag-anthrazit-ibbenbueren.de/	RAG Anthrazit Ibbenbüren GmbH Osnabrücker Straße 112 49477 Ibbenbüren	1	33
Reno De Medici Arnsberg GmbH	yes	paper production	18.11.2014 09:15 am	27.11.14	09.12.14	www.renodemedici.it	Reno De Medici Arnsberg GmbH Hellefelder Straße 51 59821 Arnsberg	1	19
RheinEnergie AG	yes	electricity generation	18.11.2014 09:15 am	27.11.14	09.12.14	http://www.rheinenergie.com	RheinEnergie AG Parkgürtel 24 D-50823 Köln	6	663
Rheinkraftwerk Albbruck- Dogern AG	yes	Electricity generation	10.11.14			http://www.radag.de/	Rheinkraftwerk Albbruck-Dogern AG Säckinger Straße 67 79725 Laufenburg Tel. +49 7763 9278-0 Fax. +49 7763 9278-70299 Email: info@radag.de	2	104

Source: German Federal Network Agency (Bundesnetzagentur), List of power plants, accessed July 16, 2014; pre-processed by the author according to the stated criteria before.
Notice: Further information, such as name and email address of contact person and details about phone calls, is available on request from the author of this thesis.

Appendix 21. (continuation) **List of survey participants**

Company name	"Electricity generation" as core competence	Details about main industry segment	Survey sent	Survey reminder 1	Survey reminder 2	Internet page	Address / Contact details	Number of power plants	Amount of net nominal capacity (in MW)
Rhein-Main-Donau AG	yes	electricity generation	18.11.2014 09:15 am	27.11.14	09.12.14	http://www.rmd.de/	Rhein-Main-Donau AG Blutenburgstraße 20 80636 München +49 89 99 222 - 0	5	123
RhönEnergie Fulda GmbH	yes	electricity generation	18.11.2014 09:15 am	27.11.14	09.12.14	http://www.re-fd.de/re-fd.php	RhönEnergie Fulda GmbH Bahnhofstraße 2 36037 Fulda Telefon: 0661 12-100	1	25
ROMONTA GmbH	yes	waste mgmt.	18.11.2014 09:15 am	27.11.14	09.12.14	http://www.wachs-und-mehr.de	ROMONTA OT Amsdorf Chausseestraße 1 D-06317 Seegebiet Mansfelder Land	1	49
RÜTGERS InfraTec GmbH	yes	electricity generation	18.11.2014 09:15 am	27.11.14	09.12.14	http://www.ruetgers-group.com	Castrop-Rauxel RÜTGERS Germany GmbH Fon +49 2305 705-523	1	10
RWE Generation SE	yes	electricity generation	18.11.14					16	4.884
RWE Innogy GmbH	yes	electricity generation	18.11.14					16	270
RWE Power AG	yes	electricity generation	18.11.14					27	10.473
Sachtleben Chemie GmbH	no	chemical	18.11.2014 09:15 am	27.11.14	09.12.14	http://www.sachtleben.de	Sachtleben Chemie GmbH Dr.-Rudolf-Sachtleben-Str. 4 D-47198 Duisburg Tel.: +49 2066 22-0	1	28
Salzgitter Flachstahl GmbH	no	metal working	18.11.2014 09:15 am	27.11.14	09.12.14	http://www.salzgitter-flachstahl.de/	Salzgitter Flachstahl GmbH Eisenhüttenstraße 99 38239 Salzgitter	3	289
Sappi Alfeld GmbH	no	paper production	18.11.14			http://www.sappi.com/regions/eu/SappiEurope/Mills/Pages/AlfeldMill.aspx	Sappi Alfeld GmbH Mühlenmasch 1 31061 Alfeld Germany	2	37
Sappi Ehingen GmbH	no	paper production	18.11.2014 09:15 am	27.11.14	09.12.14	http://www.sappi.com/regions/eu/SappiEurope/Mills/Pages/EhingenMill.aspx	Sappi Ehingen GmbH Biberacher Strasse 73 89584 Ehingen Germany	1	13
Sappi Stockstadt GmbH	no	paper production	18.11.2014 09:15 am	27.11.14	09.12.14	http://www.sappi.com/regions/eu/SappiEurope/Mills/Pages/StockstadtMill.aspx	Sappi Stockstadt GmbH Obernburger Straße 1-9 63811 Stockstadt	2	39
Sasol Solvents Germany GmbH	no	chemical	18.11.2014 09:15 am	27.11.14	09.12.14	http://www.sasolgermany.de/	Sasol Germany GmbH Anckelmannsplatz 1 20537 Hamburg	1	22
SCA HYGIENE PRODUCTS GmbH	no	paper production	18.11.2014 09:15 am	27.11.14	09.12.14	http://sca.com/de/deutschland/Home/	SCA HYGIENE PRODUCTS GMBH Sandhofer Straße 176 68305 Mannheim Tel. +49 (0)621 778-0	1	59
Schluchseewerk Aktiengesellschaft	yes	electricity generation	18.11.2014 09:15 am	27.11.14	09.12.14	http://www.schluchseewerk.de/	Schluchseewerk AG Säckinger Straße 67 79725 Laufenburg (Baden) Tel. +49 (0)7763 9278-0	5	1.740
Schoeller Technocell GmbH & Co. KG	no	paper production	18.11.2014 09:15 am	27.11.14	09.12.14	http://www.felix-schoeller.com		1	14
Shell Deutschland Oil GmbH	no	chemical	19.11.2014 08:45 am			http://www.shell.de	Shell Deutschland Oil GmbH Suhrenkamp 71 - 77 22335 Hamburg Tel.: +49 (0) 40 / 6324 - 0	1	38
SITA Abfallverwertung GmbH	yes	waste mgmt.	18.11.2014 09:15 am	27.11.14	09.12.14	https://www.sita-deutschland.de	SITA Deutschland GmbH Industriestraße 161 50999 Köln Telefon 02236 377-0	1	25
Smurfit Kappa Herzberger Papierfabrik GmbH	no	paper production	18.11.2014 09:15 am	27.11.14	09.12.14	http://www.smurfitkappa.com	Smurfit Kappa Herzberger Papierfabrik GmbH Andreasberger Straße 1 37412 Herzberg am Harz	1	19
Smurfit Kappa Zülpich Papier GmbH	no	paper production	18.11.2014 09:20 am	27.11.14	09.12.14	http://www.smurfitkappa.com	Smurfit Kappa Zülpich Papier Zülpich Paper mill Bessenicher Weg Zülpich	2	30
Société Electrique de l'Our S.A.	yes	electricity generation	19.11.2014 08:45 am			http://www.seo.lu/de/Hauptaktivitaeten/PSW-Vianden/Vorstellung	SEO S.A. Centrale de Vianden B.P. 2 L 9401 Vianden Tel: +352 849031 - 1	10	1.096
Solvay Acetow GmbH	no	chemical	18.11.2014 09:15 am	27.11.14	09.12.14	http://www.solvay.com/en/about-solvay/businesses/acetow/index.html	Solvay Acetow GmbH Solvay P&S GmbH Engesserstrasse 8 79108 Freiburg im Breisgau	1	60
Solvay Chemicals GmbH	no	chemical	18.11.2014 09:15 am	27.11.14	09.12.14	http://www.solvay.de	Solvay Chemicals GmbH Köthensche Strasse 1-3 06406 Bernburg Tel 03471 323 - 0	3	180
Spreestromerzeugungs GmbH	no	paper production	18.11.2014 09:15 am	27.11.14	09.12.14	http://www.hamburger-rieger.com/index.php?Page_ID=hamburger-rieger&Lang_ID=de	Papierfabrik Spremberg An der Heide B5 D-03130 Spremberg	1	19
Städtische Werke Energie + Wärme GmbH	yes	electricity generation	18.11.2014 09:15 am	27.11.14	09.12.14	https://www.sw-kassel.de/	Städtische Werke Aktiengesellschaft, Kassel Königstor 3-13 34117 Kassel	2	84
Stadtwerke Augsburg Energie GmbH	yes	electricity generation	10.11.14			https://www.sw-augsburg.de/index.php	Hoher Weg 1, 86152 Augsburg, Germany Phone:+49 821 65000 Stefan Schmid Technologie - Einkauf Telefon: 0821/6500-5292	2	47
Stadtwerke Bielefeld GmbH	yes	electricity generation	13.11.14	27.11.14		https://www.stadtwerke-bielefeld.de/	Schildescher Straße 16, 33611 Bielefeld, Germany Phone:+49 800 1007175	3	114

Source: German Federal Network Agency (Bundesnetzagentur), List of power plants, accessed July 16, 2014; pre-processed by the author according to the stated criteria before.
Notice: Further information, such as name and email address of contact person and details about phone calls, is available on request from the author of this thesis.

Appendix 21. (continuation) **List of survey participants**

Company name	"Electricity generation" as core competence	Details about main industry segment	Survey sent	Survey reminder 1	Survey reminder 2	Internet page	Address / Contact details	Number of power plants	Amount of net nominal capacity (in MW)
Stadtwerke Bochum Holding GmbH	yes	electricity generation	13.11.14			http://www.stadtwerke-bochum.de	Ostring 28, 44787 Bochum, Germany Phone:+49 234 9603737	1	30
Stadtwerke Brandenburg an der Havel GmbH	yes	electricity generation	13.11.14			https://www.stwb.de/	Stadtwerke Brandenburg an der Havel GmbH Packhofstraße 31 14776 Brandenburg an der Havel Telefon: 03381 752-0	1	36
Stadtwerke Duisburg AG	yes	electricity generation	13.11.14	27.11.14		http://www.stadtwerke-duisburg.de	Bungertstraße 27, 47053 Duisburg, Germany Phone:+49 203 60404	3	369
Stadtwerke Düsseldorf AG	yes	electricity generation	18.11.14			http://www.swd-ag.de	Höherweg 100, 40233 Düsseldorf, Germany Phone:+49 211 8218210	6	664
Stadtwerke Erkrath GmbH	yes	electricity generation	13.11.14	27.11.14		http://www.stadtwerke-erkrath.de	Gruitener Straße 27 40699 Erkrath T 02104 943 60 70	1	10
Stadtwerke Flensburg GmbH	yes	electricity generation	13.11.14	27.11.14		https://www.stadtwerke-flensburg.de	Batteriestraße 48, 24939 Flensburg, Germany Phone:+49 461 4870	5	147
Stadtwerke Frankfurt (Oder) GmbH	yes	electricity generation	13.11.14	27.11.14		http://www.stadtwerke-ffo.de/	Karl-Marx-Straße 195, 15230 Frankfurt (Oder), Germany Phone:+49 335 55330	1	45
Stadtwerke Hannover AG	yes	electricity generation	13.11.14	rejected		http://www.enercity.de	Stadtwerke Hannover AG Ihmeplatz 2 30449 Hannover, Germany Phone:+49 511 4300	5	1.314
Stadtwerke Karlsruhe GmbH	yes	electricity generation	13.11.14	27.11.14			Stadtwerke Karlsruhe GmbH Daxlander Straße 72 76185 Karlsruhe, Germany Phone:+49 721 5990	1	37
Stadtwerke Kempen GmbH	yes	electricity generation	13.11.14	27.11.14		http://www.stadtwerke-kempen.de	Stadtwerke Kempen GmbH Heinrich-Horten-Straße 50, 47906 Kempen, Germany Phone:+49 2152 14960	1	13
Stadtwerke Kiel AG	yes	electricity generation	18.11.14			https://www.stadtwerke-kiel.de	Stadtwerke Kiel AG Uhlenkrog 32 24113 Kiel, Germany Phone:+49 800 2471247 0431 / 594 3410	1	20
Stadtwerke Leipzig GmbH	yes	electricity generation	13.11.14	27.11.14		http://swl.de		3	203
Stadtwerke Lemgo GmbH	yes	electricity generation	13.11.14	27.11.14		http://www.stadtwerke-lemgo.de	Bruchweg 24, 32657 Lemgo, Germany Phone:+49 5261 2550	1	13
Stadtwerke München GmbH	yes	electricity generation	13.11.14			http://www.swm.de	Emmy-Noether-Straße 2, 80992 München, Germany Phone:+49 800 7967960	4	142
Stadtwerke Münster GmbH	yes	electricity generation	18.11.14				Hafenplatz 1 48155 Münster Fon 0251.694.0	1	100
Stadtwerke Rostock AG	yes	electricity generation	13.11.14	27.11.14		https://www.swrag.de	Schmarler Damm 5, 18069 Rostock, Germany Phone:+49 381 8052000	1	108
Stadtwerke Suhl/Zella-Mehlis GmbH	yes	electricity generation	13.11.14			http://www.swsz.de	Fröhliche-Mann-Straße 2, 98528 Suhl, Germany Phone:+49 3681 4950	1	14
Stadtwerke Tübingen GmbH	yes	electricity generation	18.11.2014 09:15 am	27.11.14	09.12.14	http://www.swtue.de	Eisenhutstraße 6, 72072 Tübingen, Germany Phone:+49 7071 1570	1	13
Statkraft Markets GmbH	yes	electricity generation	18.11.14			http://www.statkraft.de	Statkraft Markets GmbH Derendorfer Allee 2a 40476 Düsseldorf Germany	6	1.540
Steag GmbH	yes	electricity generation	duplicate			http://www.steag.com	STEAG GmbH Rüttenscheider Str. 1-3 45128 Essen Phone +49 201 801-00	11	4.407
STEAG New Energies GmbH	yes	electricity generation	13.11.14				St. Johanner Straße 101, 66115 Saarbrücken, Germany Phone:+49 681 949400	2	62
STEAG Power Saar GmbH	yes	electricity generation	13.11.14	27.11.14			STEAG Power Saar GmbH Trierer Straße 4 D-66111 Saarbrücken Tel.: 06 81 / 94 94 - 05	3	1.046
Steinbeis Energie GmbH	yes	electricity generation	18.11.2014 09:15 am	27.11.14	09.12.14	http://www.steinbeis-energie.de/	Steinbeis Energie GmbH Stadtstraße 20 25348 Glückstadt	1	17
Stora Enso Maxau GmbH	no	paper production	18.11.2014 09:15 am	27.11.14	09.12.14	http://www.storaenso.com/about/contacts?ct=Mill&c=Germany	Maxau Mill Mitscherlichstrasse 76187 Karlsruhe Germany	1	78
Stora Enso Sachsen GmbH	no	paper production	18.11.2014 09:20 am	27.11.14	09.12.14	http://www.storaenso.com/about/contacts?ct=Mill&c=Germany		1	47
Südzucker AG Mannheim/Ochsenfurt	no	food	18.11.2014 09:15 am	27.11.14	09.12.14	http://www.suedzucker.de/de/Unternehmen/Standorte/Zuckerfabriken-Deutschland/Werk-Ochsenfurt/	Hauptverwaltung Mannheim Marktbreiter Straße 74 97199 Ochsenfurt	1	30
Südzucker AG Mannheim/Ochsenfurt, Werk Zeitz	no	food	18.11.2014 09:20 am	27.11.14	09.12.14	http://www.suedzucker.de/de/Unternehmen/Standorte/Zuckerfabriken-Deutschland/Werk-Zeitz/	Hauptverwaltung Mannheim Albrechtstraße 54 06712 Zeitz	2	37
Suiker Unie GmbH	no	food	18.11.14			http://www.suikerunie.nl/Standorte.aspx	Bluthsluster Straße 24, 17389 Anklam, Deutschland Telefon:+49 3971 2540 105	1	15

Source: German Federal Network Agency (Bundesnetzagentur), List of power plants, accessed July 16, 2014; pre-processed by the author according to the stated criteria before.
Notice: Further information, such as name and email address of contact person and details about phone calls, is available on request from the author of this thesis.

Appendix 21. (continuation) **List of survey participants**

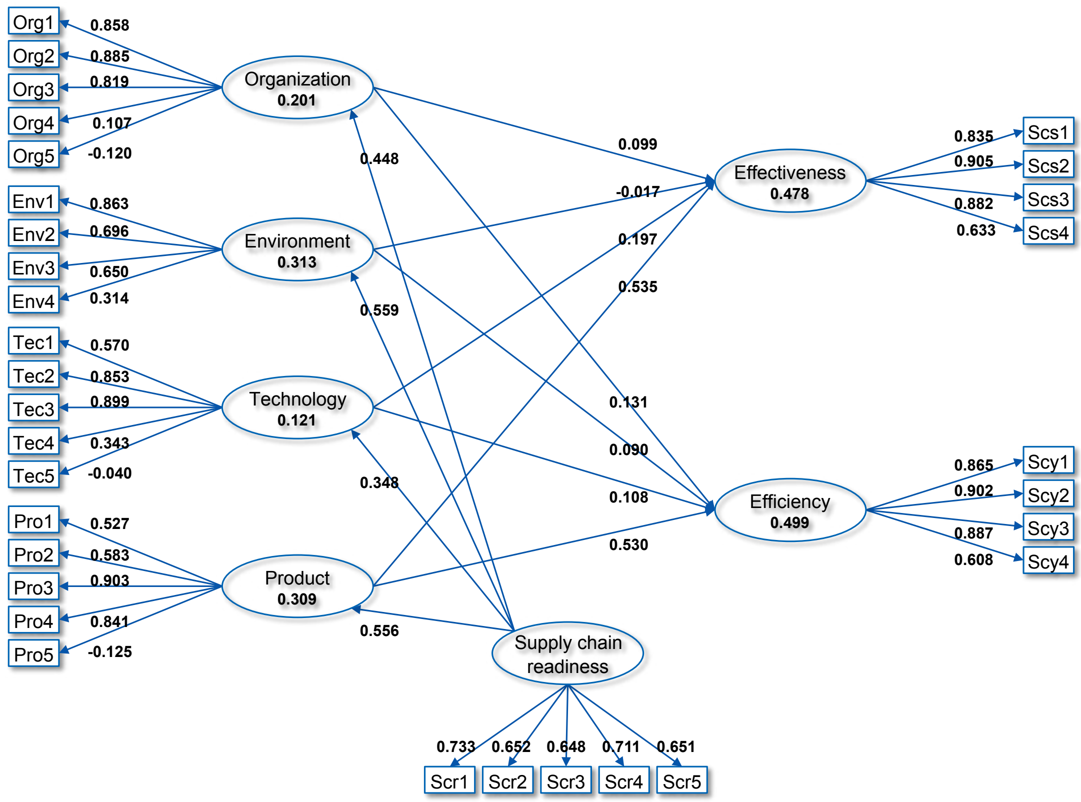
Company name	"Electricity generation" as core competence	Details about main industry segment	Survey sent	Survey reminder 1	Survey reminder 2	Internet page	Address / Contact details	Number of power plants	Amount of net nominal capacity (in MW)
swb Entsorgung GmbH & Co. KG	yes	waste mgmt.	13.11.14			https://www.swb-gruppe.de/	swb Entsorgung GmbH & Co. KG Theodor-Heuss-Allee 20 28215 Bremen	2	77
swb Erzeugung GmbH & Co. KG	yes	waste mgmt.	13.11.14	27.11.14		https://www.swb-gruppe.de/	swb Erzeugung GmbH & Co. KG Theodor-Heuss-Allee 20 28215 Bremen T 0421 359-3351	4	657
SWE Energie GmbH	yes	waste mgmt.	13.11.14	27.11.14		https://www.stadtwerke-erfurt.de/	SWE Energie GmbH Magdeburger Allee 34 99086 Erfurt Telefon: 0361 564-0	3	120
SWK - Stadtwerke Kaiserslautern	yes	electricity generation	18.11.2014 09:15 am	27.11.14	09.12.14	www.swk-kl.de/	Bismarckstraße 14, 67655 Kaiserslautern, Germany Phone:+49 631 80010	2	25
SWK ENERGIE GmbH	yes	electricity generation	18.11.2014 02:22 pm	27.11.14		https://www.swk.de/	SWK STADTWERKE KREFELD AG St. Töniser Straße 124 47804 Krefeld Tel.: 02151 – 980 Fax: 02151 – 981100	1	13
SWM Services GmbH	yes	electricity generation	duplicate			https://www.stadtwerke-neumuenster.de	SWM Services GmbH Bismarckstraße 51 24534 Neumünster, Germany Phone:+49 4321 2020	7	874
SWN Stadtwerke Neumünster GmbH	yes	electricity generation	13.11.14	27.11.14		https://www.stadtwerke-neumuenster.de	SWN Stadtwerke Neumünster GmbH Bismarckstraße 51 24534 Neumünster 04321 202-188	1	67
Technische Werke Ludwigshafen AG	yes	electricity generation	18.11.2014 09:15 am	27.11.14	09.12.14	http://www.twl.de/	Technische Werke Ludwigshafen AG Industriestraße 3 67063 Ludwigshafen Tel: 0621-505 0	1	29
Thermische Abfallbehandlung Lauta GmbH & Co. oHG	yes	electricity generation	18.11.2014 09:15 am	27.11.14	09.12.14		Thermische Abfallbehandlung Lauta GmbH & Co. oHG Industrie- u. Gewerbegebiet Lauta Straße B Nr. 5 02991 Lauta	1	16
Thüringer Energie AG	no	metal working	19.11.2014 08:45 am			http://www.thueringerenergie.de	Thüringer Energie Schwerborner Straße 30 99087 Erfurt Telefon 0361 652-0	1	182
ThyssenKrupp Steel Europe AG	no	metal working	18.11.2014 11:50 am	27.11.14		www.thyssenkrupp.com	ThyssenKrupp Steel Europe AG Kaiser-Wilhelm-Straße 100 47166 Duisburg	6	700
TIWAG-Tiroler Wasserkraft AG	*yes*	electricity generation	18.11.2014 09:15 am	27.11.14	09.12.14	https://www.tiroler-wasserkraft.at	*TIWAG-Tiroler Wasserkraft AG Zentraler Einkauf Lieberstraße 3 6020 Innsbruck*	7	1.409
TOTAL Raffinerie Mitteldeutschland GmbH	no	chemical	18.11.2014 09:15 am	27.11.14	09.12.14	http://www.total.de/ueber-total/profil_in_deutschland/raffinerie_mitteldeutschland.html	TOTAL Raffinerie Mitteldeutschland GmbH Maienweg 1 06237 Leuna	1	93
Trianel Gaskraftwerk Hamm GmbH & Co. KG	*yes*	electricity generation	18.11.2014 09:15 am	27.11.14	09.12.14	http://www.trianel-hamm.de/	Trianel Gaskraftwerk Hamm GmbH & Co. KG Trianelstr. 1 D-59071 Hamm T +49 2388 30 10-810	2	838
Trianel Kohlekraftwerk Lünen GmbH & Co. KG	*yes*	electricity generation	18.11.2014 09:15 am	27.11.14	09.12.14	http://www.trianel-luenen.de	Trianel Kohlekraftwerk Lünen Frydagstraße 40 44536 Lünen	1	746
Universität Stuttgart	*no*	education	18.11.2014 02:22 pm			http://www.uni-stuttgart.de/hkw/kontakt/index.html	Universität Stuttgart Heizkraftwerk Pfaffenwald Pfaffenwaldring 8 70569 Stuttgart +49 711 685 63475	3	35
Universitätsklinikum Freiburg AdöR	*yes*	education	18.11.2014 02:31 pm	*27.11.14*		http://www.uniklinik-freiburg	Universitätsklinikum Freiburg Hartmannstraße 1 79106 Freiburg	1	25
UPM GmbH	*yes*	electricity generation	18.11.2014 09:15 am	27.11.14	09.12.14		UPM Schongau Friedrich-Haindl-Straße 10 86956 Schongau Tel.: +49 8861 213-0	3	85
UPM GmbH Werk Schwedt	*yes*	electricity generation	18.11.2014 09:15 am	27.11.14	09.12.14		UPM Schwendt Kuhheide 1 16303 Schwedt/Oder Tel.: +49 3332 281-0	1	13
VASA Kraftwerke-Pool GmbH & Co. KG	*yes*	electricity generation	n/a				VASA Kraftwerke-Pool GmbH & Co. KG Athenslebener Weg 57 39418 Staßfurt Sachsen-Anhalt	1	22
Vattenfall Europe Generation AG	*yes*	electricity generation	27.11.2014 1:00 pm			www.vattenfall.de	Vattenfall Europe Generation AG Kraftwerk Boxberg Boxberg/Oberlausitz Deutschland +49 35774 466	39	11.186
Vattenfall Europe New Energy Ecopower GmbH	*yes*	electricity generation	27.11.2014 1:00 pm			www.vattenfall.de	Vattenfall Europe New Energy Ecopower GmbH Adresse: Ost-West-Str. 25, 18147 Rostock	2	47

Source: German Federal Network Agency (Bundesnetzagentur), List of power plants, accessed July 16, 2014; pre-processed by the author according to the stated criteria before.
Notice: Further information, such as name and email address of contact person and details about phone calls, is available on request from the author of this thesis.

Appendix 21. (continuation) **List of survey participants**

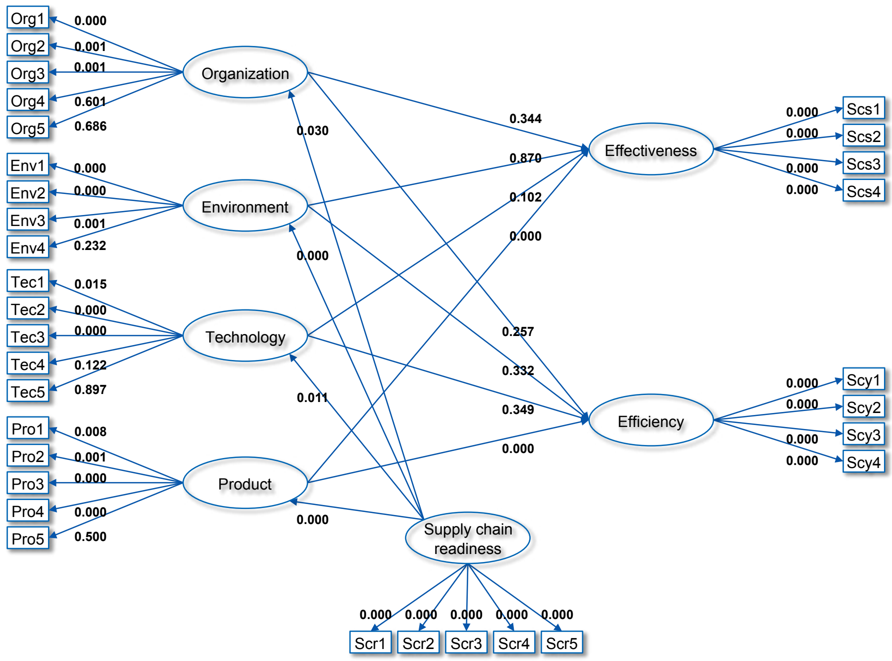
Company name	"Electricity generation" as core competence	Details about main industry segment	Survey sent	Survey reminder 1	Survey reminder 2	Internet page	Address / Contact details	Number of power plants	Amount of net nominal capacity (in MW)
Vattenfall Europe Wärme AG	yes	electricity generation	duplicate					9	2.043
Vattenfall Europe Wärme Aktiengesellschaft	yes	electricity generation	duplicate					7	785
VERBUND-Innkraftwerke GmbH	yes	electricity generation	18.11.2014 09:15 am	27.11.14	09.12.14	http://www.verbund.com	VERBUND AG Postfach 8400 1011 Wien Österreich	9	301
Vereinigte Wertach-Elektrizitätswerke GmbH	yes	electricity generation	18.11.2014 09:15 am	27.11.14	09.12.14	http://www.vwew-energie.de/	Vereinigte Wertach-Elektrizitätswerke GmbH Neugablonzer Straße 21 87600 Kaufbeuren Telefon: 08341 805-0	2	23
Versorgungs- und Verkehrsgesellschaft Saarbrücken mbH	yes	electricity generation	18.11.2014 09:15 am	27.11.14	09.12.14	http://www.vvs-konzern.de/	Versorgungs- und Verkehrsgesellschaft Saarbrücken mbH Hohenzollernstraße 104-106 66117 Saarbrücken Tel.: 0681 587-0	1	39
Voith Dienstleistungen und Grundstücks GmbH & Co. KG	yes	electricity generation	18.11.2014 09:15 am	27.11.14	09.12.14	http://voith.com/ger-de/heidenheim-80.htm	Voith GmbH St. Pöltener Straße 43 89522 Heidenheim	2	27
Volkswagen AG	no	automotive	19.11.2014 08:45 am			http://www.vw-kraftwerk.de/	VW Kraftwerk GmbH Brieffach 0112 38436 Wolfsburg Telefon +49-5361-9-23170	5	478
VSE AG, Kraftwerk Ensdorf	yes	electricity generation	18.11.2014 09:15 am	27.11.14	09.12.14	https://www.vse.de/leistungen/energie/geschaeftskunden/konventionelle-energieerzeugung/?no_cache=1	Kraftwerk Ensdorf Kurt-Kessler-Straße 1 66806 Ensdorf Telefon: 06831 502-6202	1	106
Wacker Chemie AG	no	chemical	18.11.2014 09:15 am	25.11.2014 gmx-Mail	09.12.14	http://www.wacker.com/cms/de/wacker_group/wacker_facts/sites/burghausen/burghausen.jsp?cid=11:burghausen	Wacker Chemie AG Werk Burghausen Johannes-Hess-Strasse 24 84489 Burghausen Vermittlung: +49 8677 83-0	2	223
WSW Energie & Wasser AG	yes	electricity generation	18.11.2014 09:15 am	27.11.14	09.12.14	http://www.wsw-online.de	Bromberger Str. 39 - 41 42281 Wuppertal Tel.: 0202 569-0	3	227
Zellstoff Stendal GmbH	yes	electricity generation	18.11.14			http://www.verbund.com/cc/de/ueber-uns/einkauf-beschaffung	Goldbecker Straße 1, 39596 Arneburg, Germany Phone:+49 39321 550	1	137
Zellstoff- und Papierfabrik Rosenthal GmbH	no	paper production	18.11.2014 09:15 am	27.11.14	09.12.14	http://www.zpr.de/	Zellstoff - und Papierfabrik Rosenthal GmbH Hauptstraße 16 D-07366 Blankenstein (Saale)	1	54
Zweckverband Abfallverwertung Südostbayern	yes	waste mgmt.	18.11.2014 09:15 am	27.11.14	09.12.14	http://www.zas-burgkirchen.de/	ZAS Zweckverband Abfallverwertung Südostbayern Bruck 110 84508 Burgkirchen	1	13
Zweckverband Abfallwirtschaft Raum Würzburg	yes	waste mgmt.	18.11.2014 09:15 am	27.11.14	09.12.14	http://www.zvaws.de/	Zweckverband Abfallwirtschaft Raum Würzburg Eichhornstr. 5 D-97070 Würzburg Tel.: +49 (0)931 660 58 0	1	12
Zweckverband für Abfallwirtschaft Südwestthüringen (ZASt)	yes	waste mgmt.	18.11.2014 09:15 am	27.11.14	09.12.14	http://www.zast.info/zast.html	Zeckverband für Abfallwirtschaft Südwestthüringen (ZASt) Am Schießstand 15 98544 Zella-Mehlis Tel: (03682) 4788-0	1	11
Zweckverband Müllverwertung Schwandorf	yes	waste mgmt.	18.11.2014 09:15 am	27.11.14	09.12.14	http://z-m-s.de/muellkraftwerk/index.html	Zweckverband Müllverwertung Schwandorf Alustraße 7 92421 Schwandorf Tel.: (0 94 31) 631 -0	1	54
Zweckverband Müllverwertungsanlage Ingolstadt (MVA Ingolstadt)	yes	waste mgmt.	18.11.2014 09:15 am	27.11.14	09.12.14	http://www.mva-ingolstadt.de	Zweckverband Müllverwertungsanlage Ingolstadt Am Mailinger Bach 141 85055 Ingolstadt	1	26

Source: German Federal Network Agency (Bundesnetzagentur), List of power plants, accessed July 16, 2014; pre-processed by the author according to the stated criteria before.
Notice: Further information, such as name and email address of contact person and details about phone calls, is available on request from the author of this thesis.



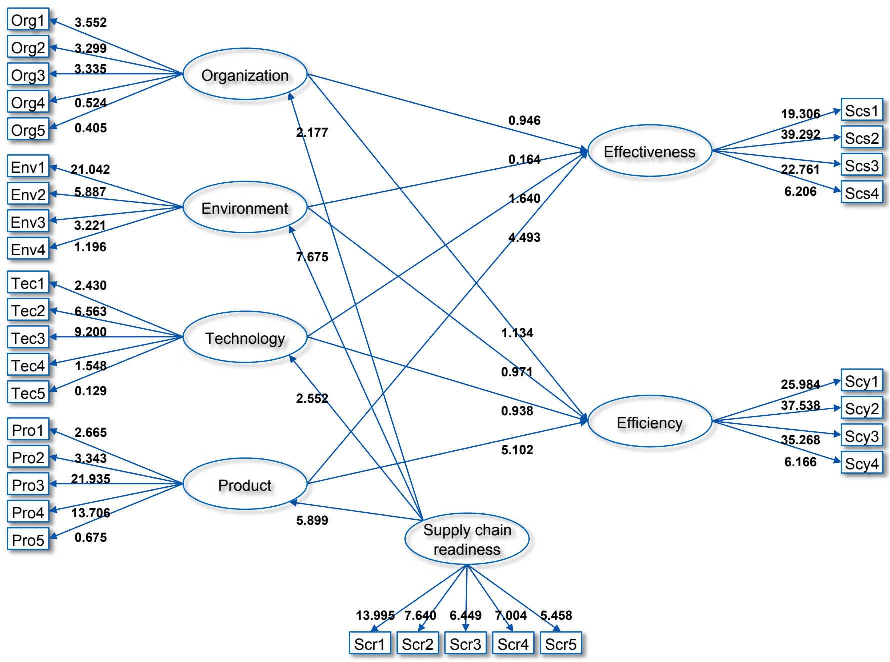
Source: compiled by author. Analysis is based on 110 responses to a questionnaire survey (November 2014 to February 2015) from supply chain members of the German electricity power generation industry.

Appendix 22. **Variant 'in general' - PLS algorithm (R Square and loadings)**



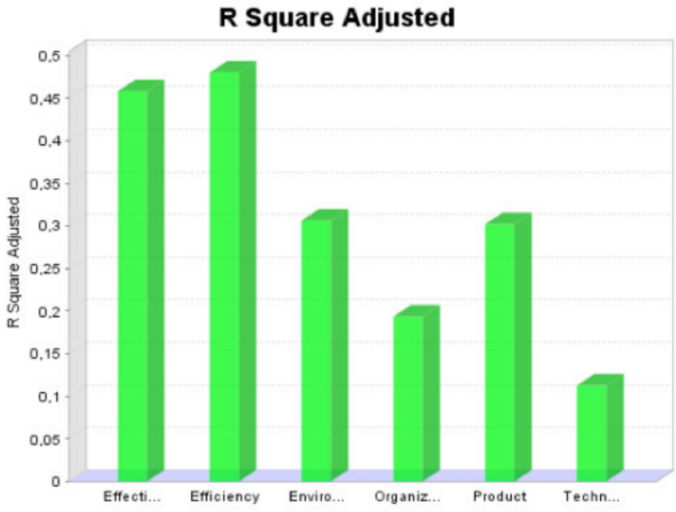
Source: compiled by author. Analysis is based on 110 responses to a questionnaire survey (November 2014 to February 2015) from supply chain members of the German electricity power generation industry.

Appendix 23. **Variant 'in general' - Bootstrapping (p-values)**



Source: compiled by author. Analysis is based on 110 responses to a questionnaire survey (November 2014 to February 2015) from supply chain members of the German electricity power generation industry.

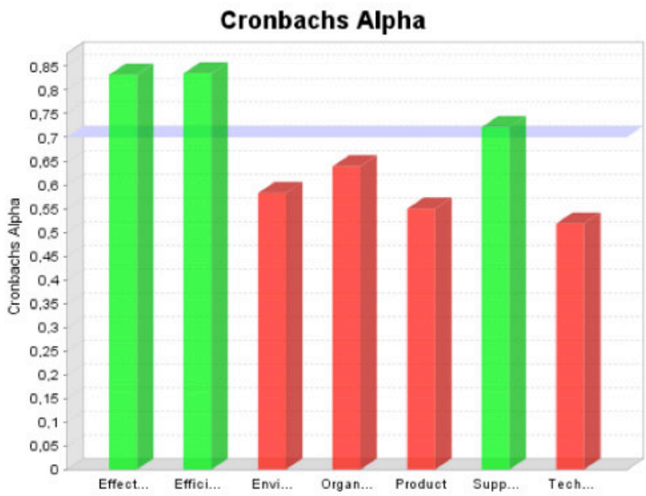
Appendix 24. **Variant 'in general' - Bootstrapping (t-values)**



	R Square
Effectivness	0,458
Efficiency	0,480
Environment	0,306
Organization	0,194
Product	0,302
Technology	0,113

Source: compiled by author. Analysis is based on 110 responses to a questionnaire survey (November 2014 to February 2015) from supply chain members of the German electricity power generation industry.

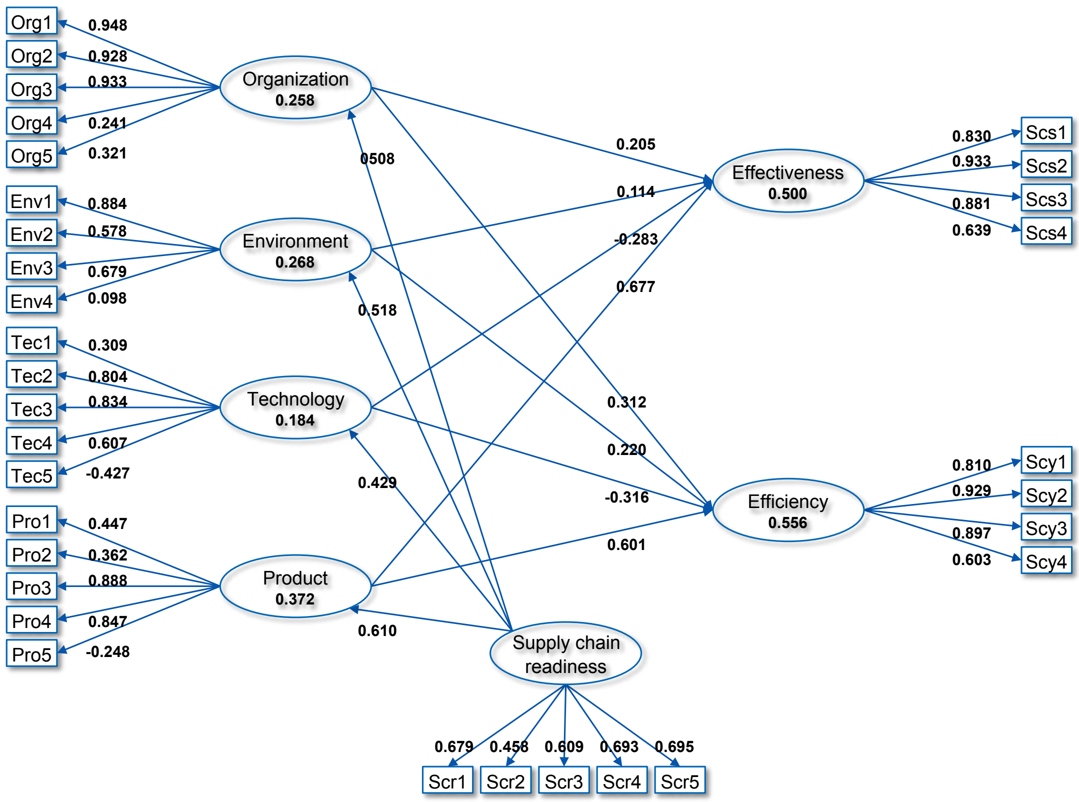
Appendix 25. **Variant 'in general' - R Square adjusted**



	Cronbachs Alpha
Effectivness	0,833
Efficiency	0,835
Environment	0,583
Organization	0,640
Product	0,550
Supply chain readyness	0,722
Technology	0,519

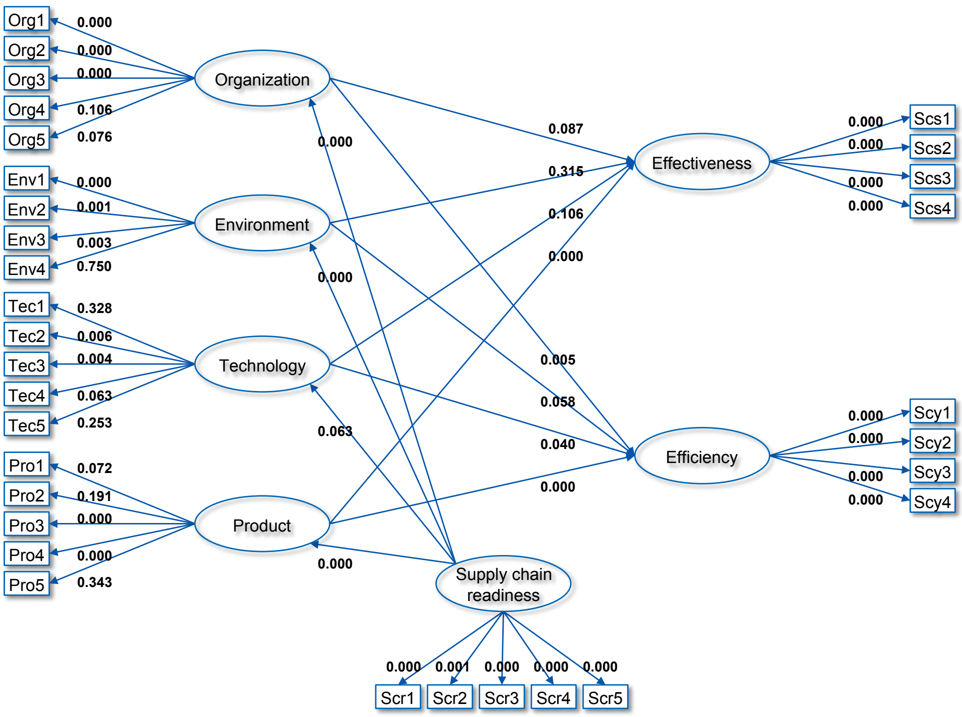
Source: compiled by author. Analysis is based on 110 responses to a questionnaire survey (November 2014 to February 2015) from supply chain members of the German electricity power generation industry.

Appendix 26. **Variant 'in general' - Cronbach's alpha**



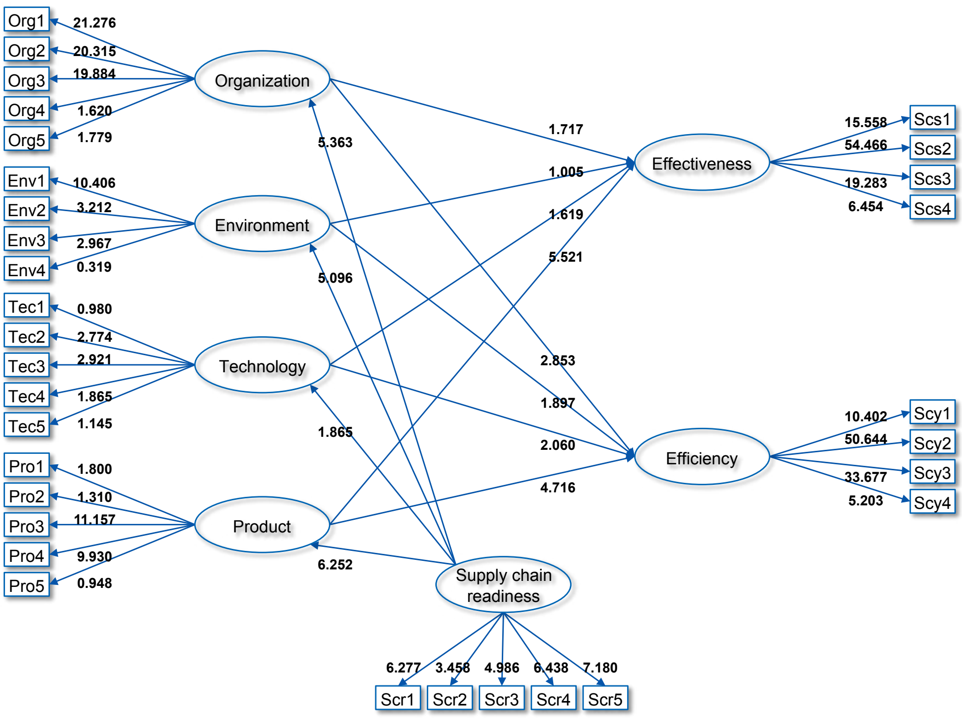
Source: compiled by author. Analysis is based on 110 responses to a questionnaire survey (November 2014 to February 2015) from supply chain members of the German electricity power generation industry.

Appendix 27. **Variant 'bar code' - PLS algorithm (R Square and loadings)**



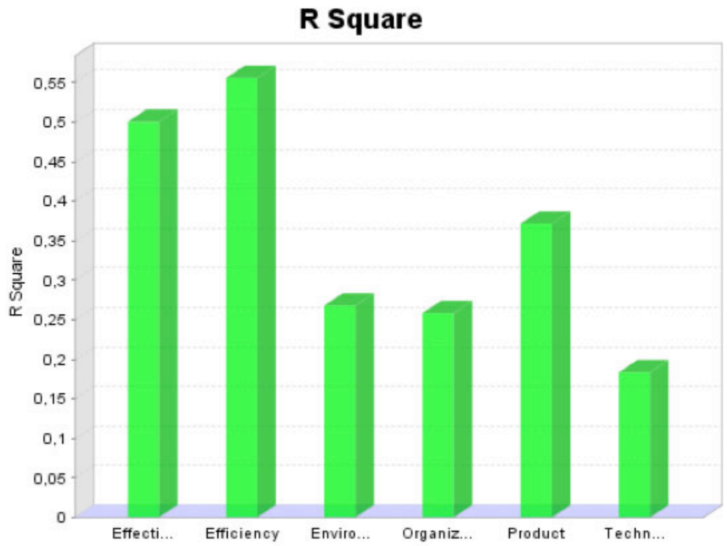
Source: compiled by author. Analysis is based on 110 responses to a questionnaire survey (November 2014 to February 2015) from supply chain members of the German electricity power generation industry.

Appendix 28. **Variant 'bar code' - Bootstrapping (p-values)**

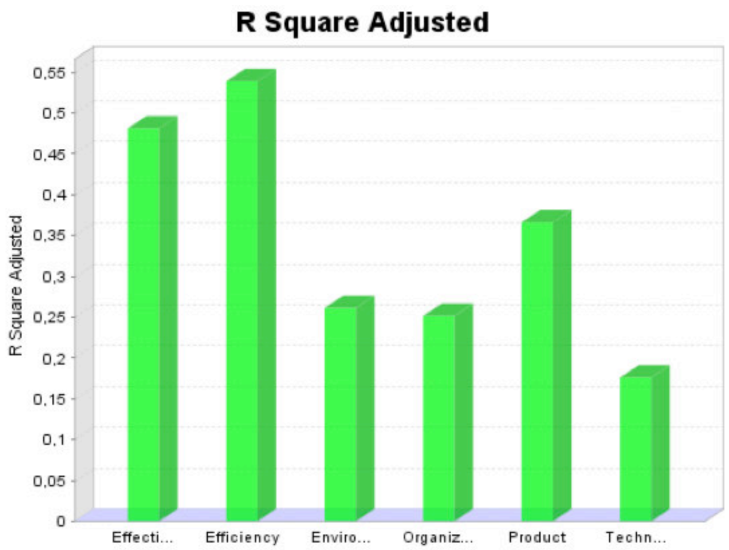


Source: compiled by author. Analysis is based on 110 responses to a questionnaire survey (November 2014 to February 2015) from supply chain members of the German electricity power generation industry.

Appendix 29. **Variant 'bar code' - Bootstrapping (t-values)**



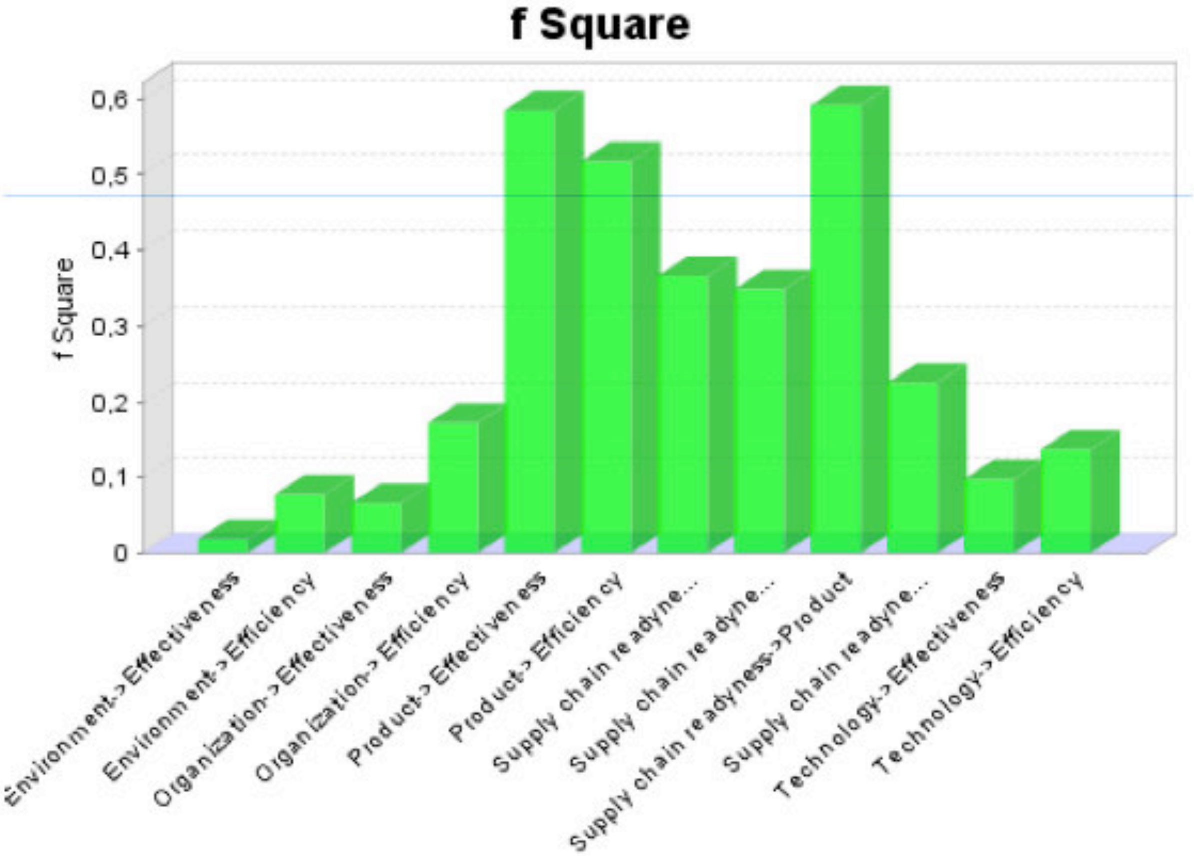
	R Square
Effectiveness	0,500
Efficiency	0,556
Environment	0,268
Organization	0,258
Product	0,372
Technology	0,184



	R Square
Effectiveness	0,481
Efficiency	0,539
Environment	0,261
Organization	0,252
Product	0,366
Technology	0,176

Source: compiled by author. Analysis is based on 110 responses to a questionnaire survey (November 2014 to February 2015) from supply chain members of the German electricity power generation industry.

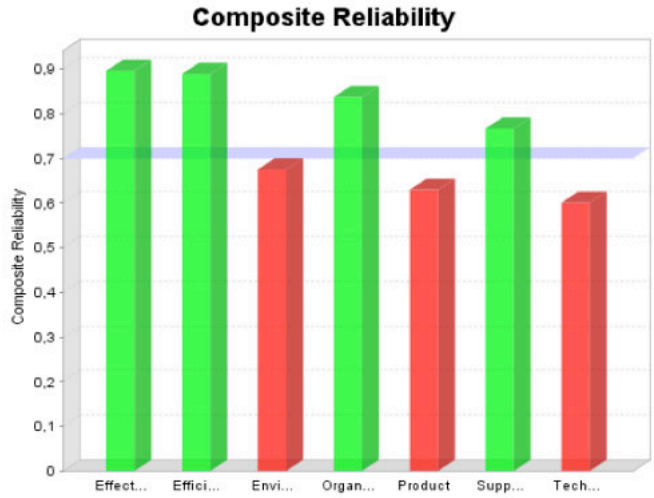
Appendix 30. **Variant 'bar code' - R Square and R Square adjusted**



	Effectiveness	Efficiency	Environment	Organization	Product	Supply chain readyness	Technology
Effectiveness							
Efficiency							
Environment	0,018	0,077					
Organization	0,066	0,172					
Product	0,585	0,518					
Supply chain readyness			0,366	0,349	0,592		0,225
Technology	0,098	0,137					

Source: compiled by author. Analysis is based on 110 responses to a questionnaire survey (November 2014 to February 2015) from supply chain members of the German electricity power generation industry.

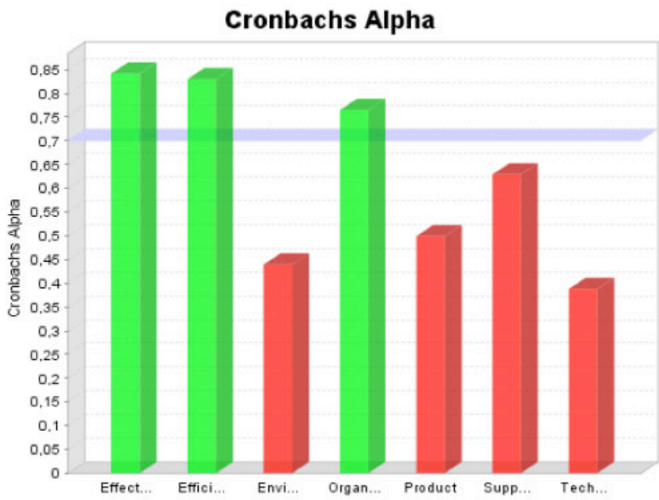
Appendix 31. **Variant 'bar code' - f Square**



	Composite Reliability
Effectiveness	0,896
Efficiency	0,889
Environment	0,675
Organization	0,837
Product	0,629
Supply chain readyness	0,766
Technology	0,601

Source: compiled by author. Analysis is based on 110 responses to a questionnaire survey (November 2014 to February 2015) from supply chain members of the German electricity power generation industry.

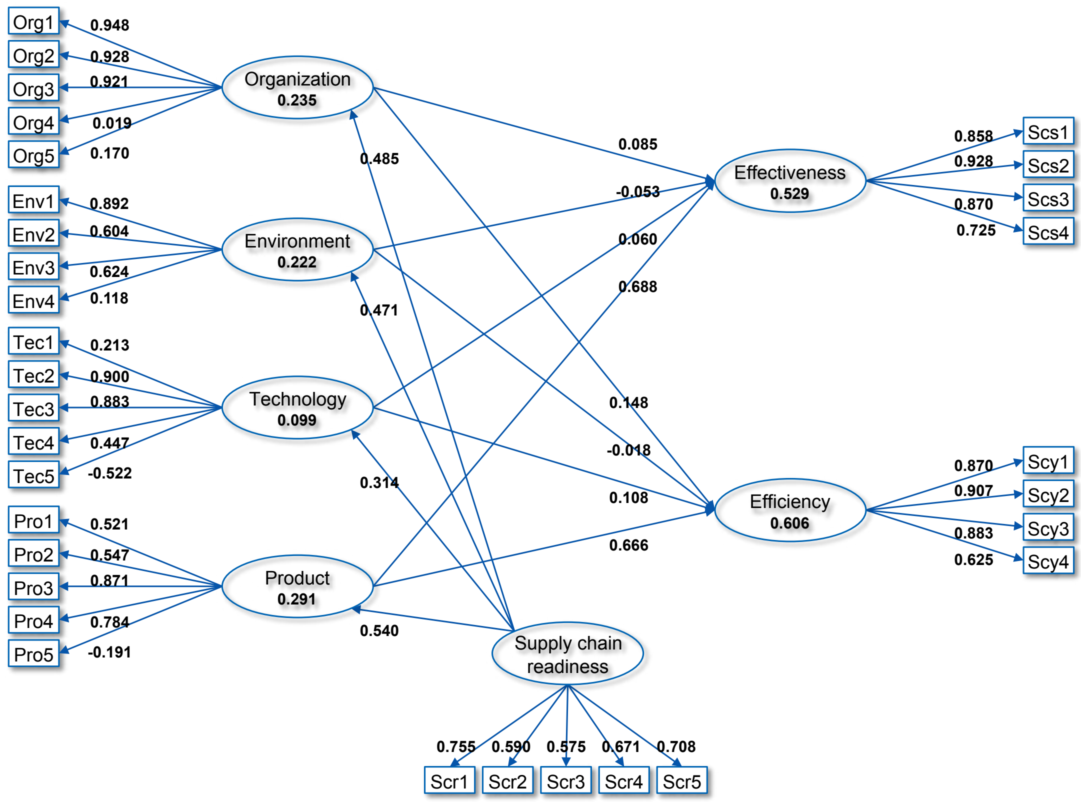
Appendix 32. **Variant 'bar code' - Composite reliability**



	Cronbachs Alpha
Effectiveness	0,842
Efficiency	0,830
Environment	0,439
Organization	0,765
Product	0,499
Supply chain readyness	0,629
Technology	0,388

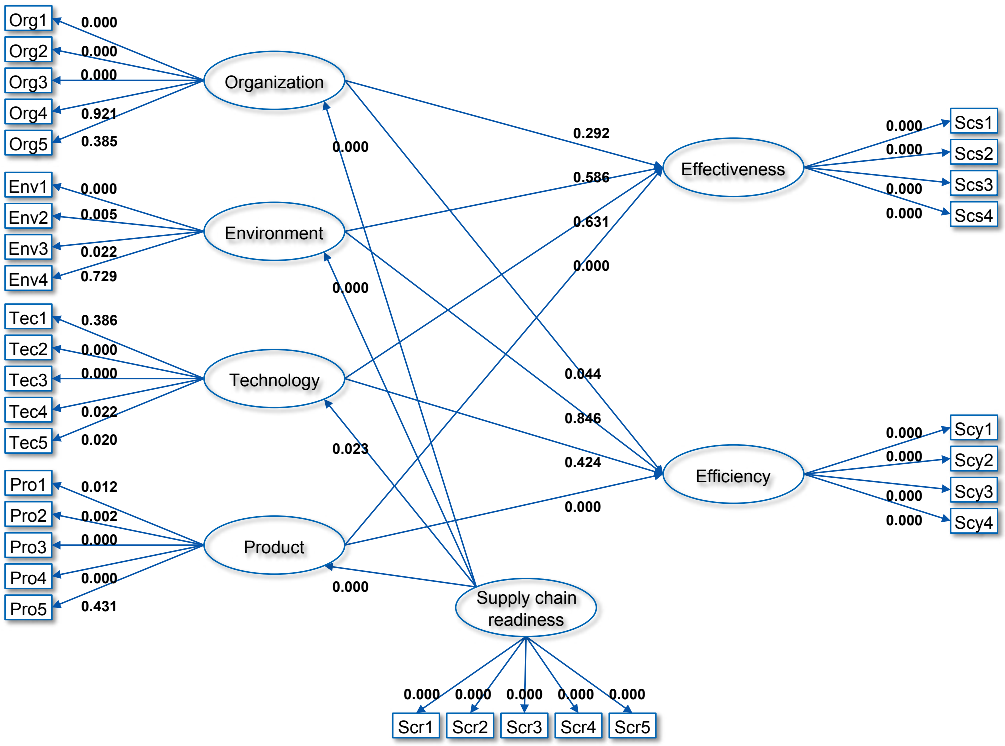
Source: compiled by author. Analysis is based on 110 responses to a questionnaire survey (November 2014 to February 2015) from supply chain members of the German electricity power generation industry.

Appendix 33. **Variant 'bar code' - Cronbach's alpha**



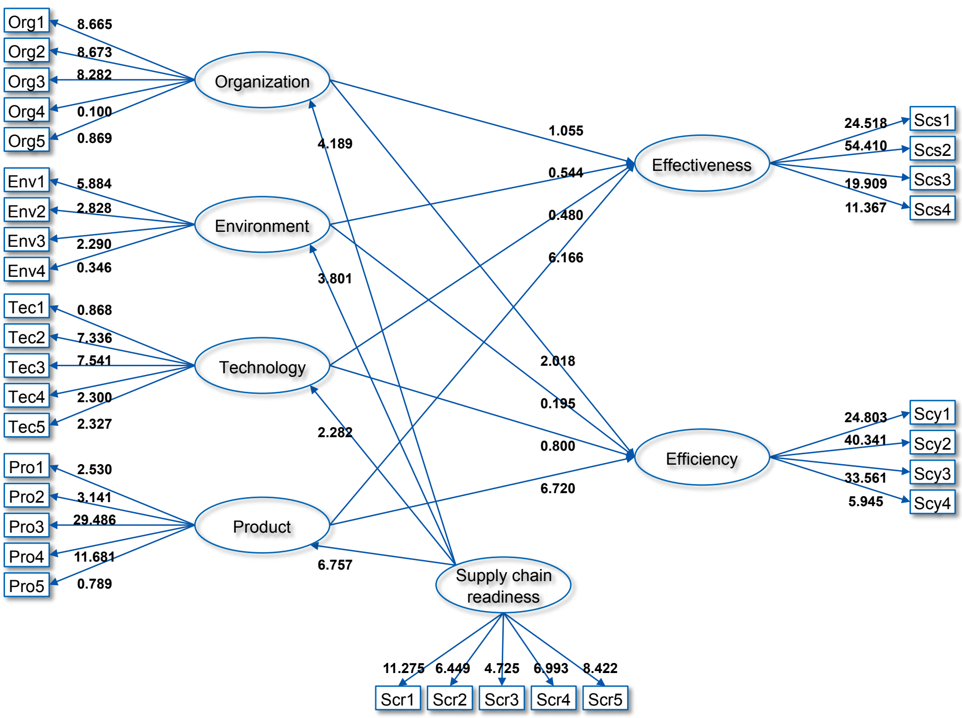
Source: compiled by author. Analysis is based on 110 responses to a questionnaire survey (November 2014 to February 2015) from supply chain members of the German electricity power generation industry.

Appendix 34. **Variant 'RFID' - PLS algorithm (R Square and loadings)**



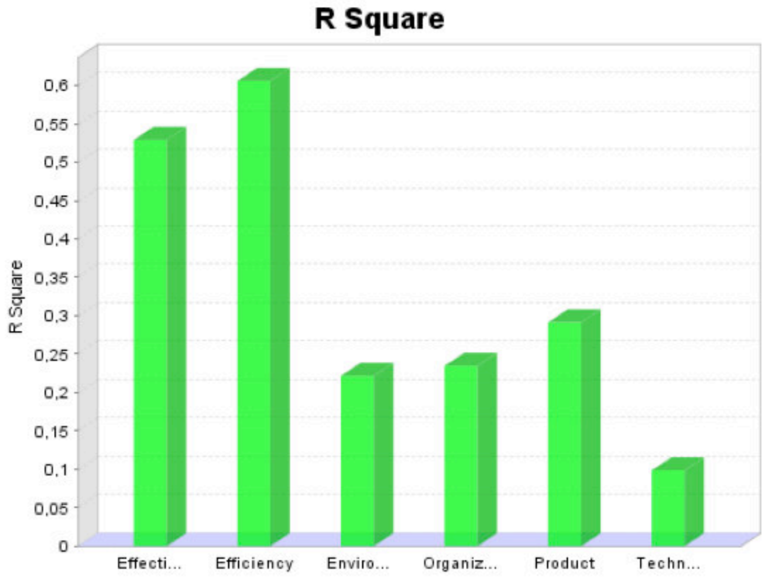
Source: compiled by author. Analysis is based on 110 responses to a questionnaire survey (November 2014 to February 2015) from supply chain members of the German electricity power generation industry.

Appendix 35. **Variant 'RFID' - Bootstrapping (p-values)**

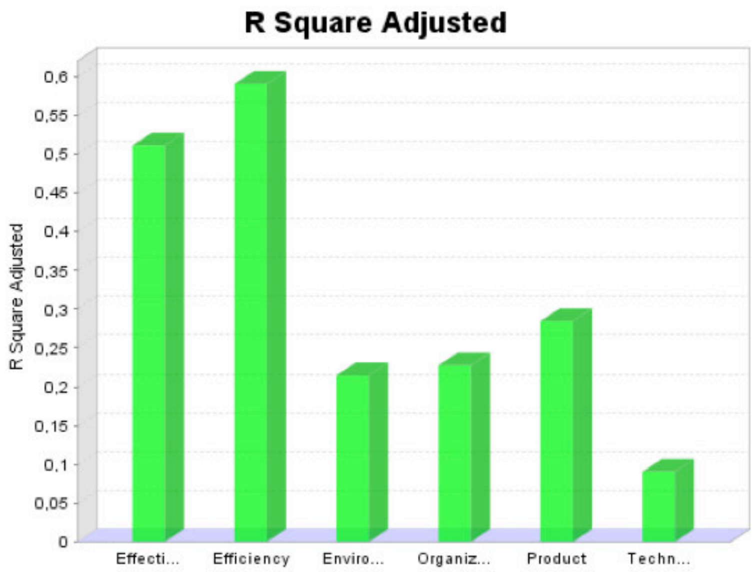


Source: compiled by author. Analysis is based on 110 responses to a questionnaire survey (November 2014 to February 2015) from supply chain members of the German electricity power generation industry.

Appendix 36. **Variant 'RFID' - Bootstrapping (t-values)**



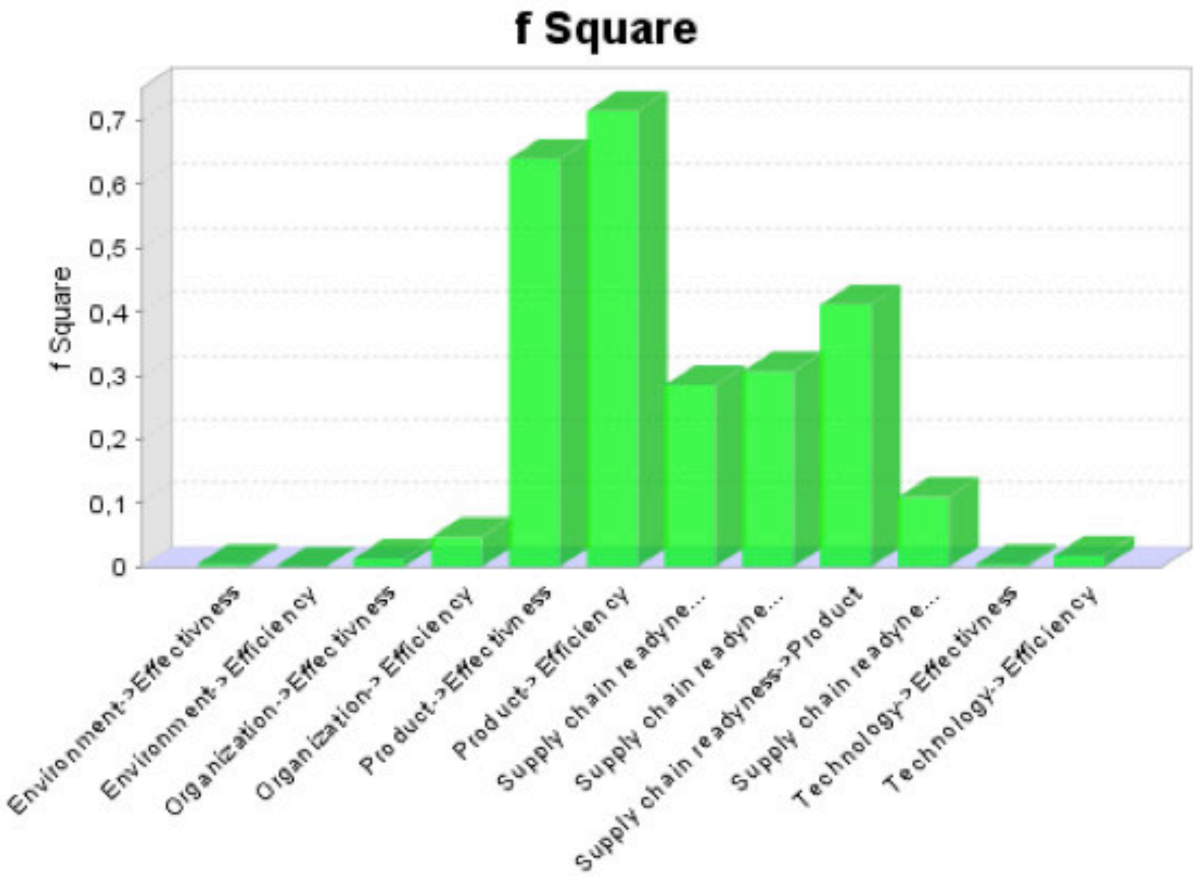
	R Square
Effectivness	0,529
Efficiency	0,606
Environment	0,222
Organization	0,235
Product	0,291
Technology	0,099



	R Square
Effectivness	0,511
Efficiency	0,591
Environment	0,215
Organization	0,228
Product	0,285
Technology	0,091

Source: compiled by author. Analysis is based on 110 responses to a questionnaire survey (November 2014 to February 2015) from supply chain members of the German electricity power generation industry.

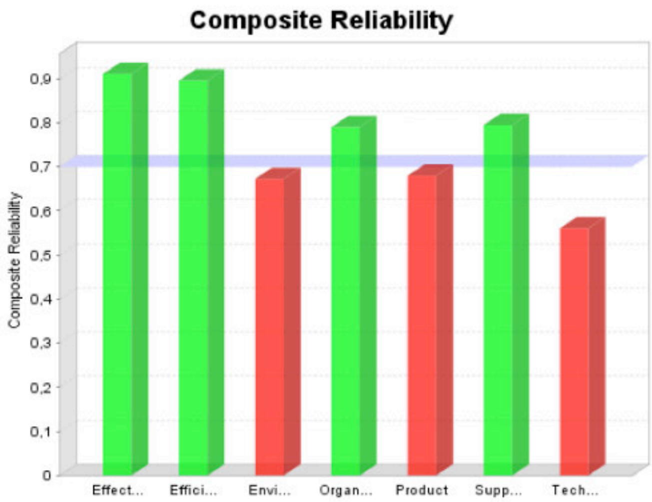
Appendix 37. **Variant 'RFID' - R Square and R Square adjusted**



	Effectivness	Efficiency	Environment	Organization	Product	Supply chain readyness	Technology
Effectivness							
Efficiency							
Environment	0,005	0,001					
Organization	0,013	0,047					
Product	0,640	0,715					
Supply chain readyness			0,285	0,307	0,411		0,110
Technology	0,005	0,018					

Source: compiled by author. Analysis is based on 110 responses to a questionnaire survey (November 2014 to February 2015) from supply chain members of the German electricity power generation industry.

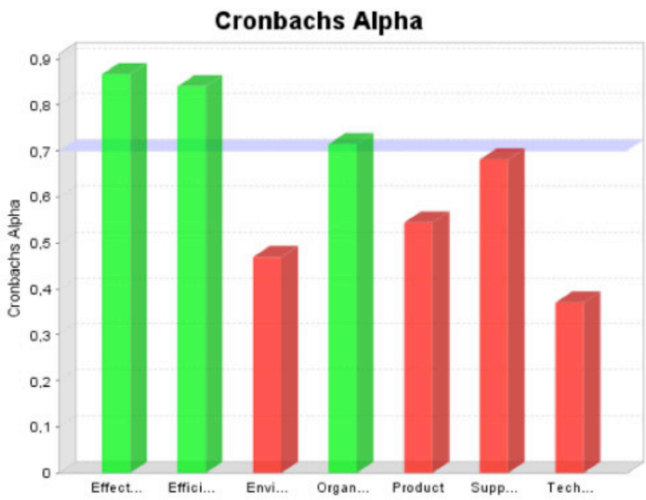
Appendix 38. **Variant 'RFID' - f Square**



	Composite Reliability
Effectivness	0,911
Efficiency	0,896
Environment	0,673
Organization	0,790
Product	0,680
Supply chain readyness	0,795
Technology	0,561

Source: compiled by author. Analysis is based on 110 responses to a questionnaire survey (November 2014 to February 2015) from supply chain members of the German electricity power generation industry.

Appendix 39. **Variant 'RFID' - Composite reliability**



	Cronbachs Alpha
Effectivness	0,867
Efficiency	0,841
Environment	0,470
Organization	0,715
Product	0,545
Supply chain readyness	0,681
Technology	0,370

Source: compiled by author. Analysis is based on 110 responses to a questionnaire survey (November 2014 to February 2015) from supply chain members of the German electricity power generation industry.

Appendix 40. **Variant 'RFID' - Cronbach's alpha**

Variable	R Square		
	Variant 'in general'	Variant 'bar code'	Variant 'RFID'
Organizational characteristics (Org)	0.201	0.258	0.235
Environmental characteristics (Env)	0.313	0.268	0.222
Technological fit (Tec)	0.121	0.184	0.099
Product context (Pro)	0.309	0.372	0.291
Supply chain effectiveness (Scs)	0.478	0.500	0,529
Supply chain efficiency (Scy)	0.499	0.556	0.606

Source: compiled by author. Analysis is based on 110 responses to a questionnaire survey (November 2014 to February 2015) from supply chain members of the German electricity power generation industry.

Appendix 41. **Comparison R Square of 'in general', 'bar code', and 'RFID'**

One-Sample Kolmogorov-Smirnov Test

		Envir	Organization	Product	Technology
N		220	220	220	220
Normal Parameters[a,b]	Mean	,00001	,00005	,00002	,00004
	Std. Deviation	1,002298	1,002283	1,002277	1,002272
Most Extreme Differences	Absolute	,155	,130	,162	,192
	Positive	,123	,130	,141	,192
	Negative	-,155	-,073	-,162	-,103
Test Statistic		,155	,130	,162	,192
Asymp. Sig. (2-tailed)		,000[c]	,000[c]	,000[c]	,000[c]

One-Sample Kolmogorov-Smirnov Test

		SCR
N		220
Normal Parameters[a,b]	Mean	,00000
	Std. Deviation	1,002287
Most Extreme Differences	Absolute	,156
	Positive	,156
	Negative	-,142
Test Statistic		,156
Asymp. Sig. (2-tailed)		,000[c]

a. Test distribution is Normal.

b. Calculated from data.

c. Lilliefors Significance Correction.

Source: compiled by author. Analysis is based on 110 responses to a questionnaire survey (November 2014 to February 2015) from supply chain members of the German electricity power generation industry.

Appendix 42. **Comparison 'bar code' and 'RFID' - nonparametric test**

Group Statistics

	BC_RFID	N	Mean	Std. Deviation	Std. Error Mean
Envir	0	110	-,00003	1,004574	,095782
	1	110	,00005	1,004615	,095786
Organization	0	110	,00004	1,004592	,095784
	1	110	,00006	1,004567	,095782
Product	0	110	,00003	1,004608	,095786
	1	110	,00002	1,004539	,095779
Technology	0	110	,00001	1,004577	,095783
	1	110	,00007	1,004559	,095781
SCR	0	110	-,00001	1,004558	,095781
	1	110	,00001	1,004608	,095786

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means	
		F	Sig.	t	df
Envir	Equal variances assumed	,030	,862	-,001	218
	Equal variances not assumed			-,001	218,000
Organization	Equal variances assumed	,025	,874	,000	218
	Equal variances not assumed			,000	218,000
Product	Equal variances assumed	,011	,917	,000	218
	Equal variances not assumed			,000	218,000
Technology	Equal variances assumed	,000	,985	,000	218
	Equal variances not assumed			,000	218,000

Source: compiled by author. Analysis is based on 110 responses to a questionnaire survey (November 2014 to February 2015) from supply chain members of the German electricity power generation industry.

Appendix 43. **Comparison 'bar code' and 'RFID' – t-test for all groups**

Independent Samples Test

		t-test for Equality of Means		
		Sig. (2-tailed)	Mean Difference	Std. Error Difference
Envir	Equal variances assumed	1,000	-,000073	,135459
	Equal variances not assumed	1,000	-,000073	,135459
Organization	Equal variances assumed	1,000	-,000027	,135457
	Equal variances not assumed	1,000	-,000027	,135457
Product	Equal variances assumed	1,000	,000009	,135457
	Equal variances not assumed	1,000	,000009	,135457
Technology	Equal variances assumed	1,000	-,000064	,135456
	Equal variances not assumed	1,000	-,000064	,135456

Independent Samples Test

		t-test for Equality of Means	
		95% Confidence Interval of the Difference	
		Lower	Upper
Envir	Equal variances assumed	-,267051	,266905
	Equal variances not assumed	-,267051	,266905
Organization	Equal variances assumed	-,267001	,266947
	Equal variances not assumed	-,267001	,266947
Product	Equal variances assumed	-,266963	,266981
	Equal variances not assumed	-,266963	,266981
Technology	Equal variances assumed	-,267034	,266907
	Equal variances not assumed	-,267034	,266907

Source: compiled by author. Analysis is based on 110 responses to a questionnaire survey (November 2014 to February 2015) from supply chain members of the German electricity power generation industry.

Appendix 43. (continuation) **Comparison 'bar code' and 'RFID' – t-test for all groups**

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means	
		F	Sig.	t	df
SCR	Equal variances assumed	,022	,881	,000	218
	Equal variances not assumed			,000	218,000

Independent Samples Test

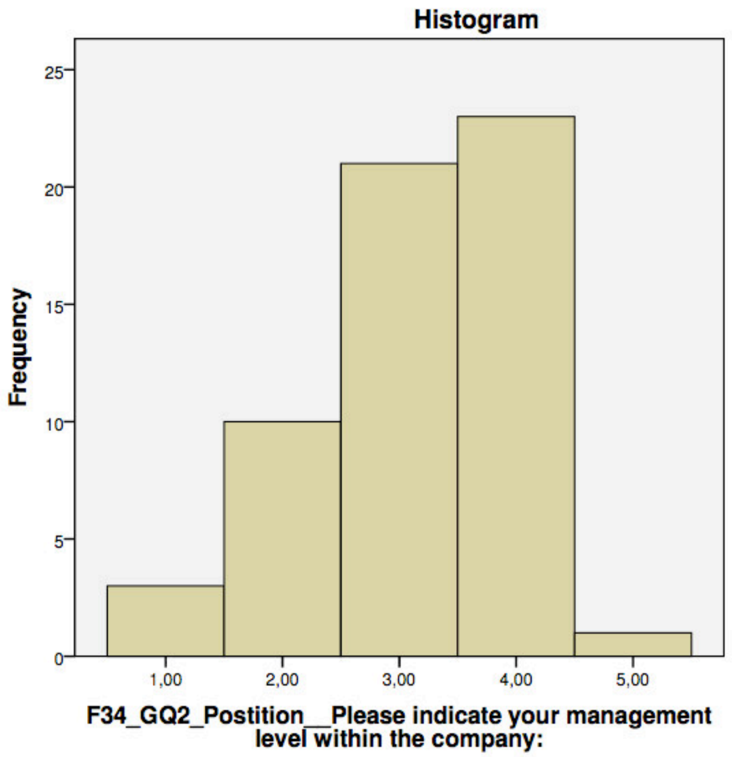
		t-test for Equality of Means		
		Sig. (2-tailed)	Mean Difference	Std. Error Difference
SCR	Equal variances assumed	1,000	-,000018	,135458
	Equal variances not assumed	1,000	-,000018	,135458

Independent Samples Test

		t-test for Equality of Means	
		95% Confidence Interval of the Difference	
		Lower	Upper
SCR	Equal variances assumed	-,266993	,266957
	Equal variances not assumed	-,266993	,266957

Source: compiled by author. Analysis is based on 110 responses to a questionnaire survey (November 2014 to February 2015) from supply chain members of the German electricity power generation industry.

Appendix 43. (continuation) **Comparison 'bar code' and 'RFID' – t-test for all groups**

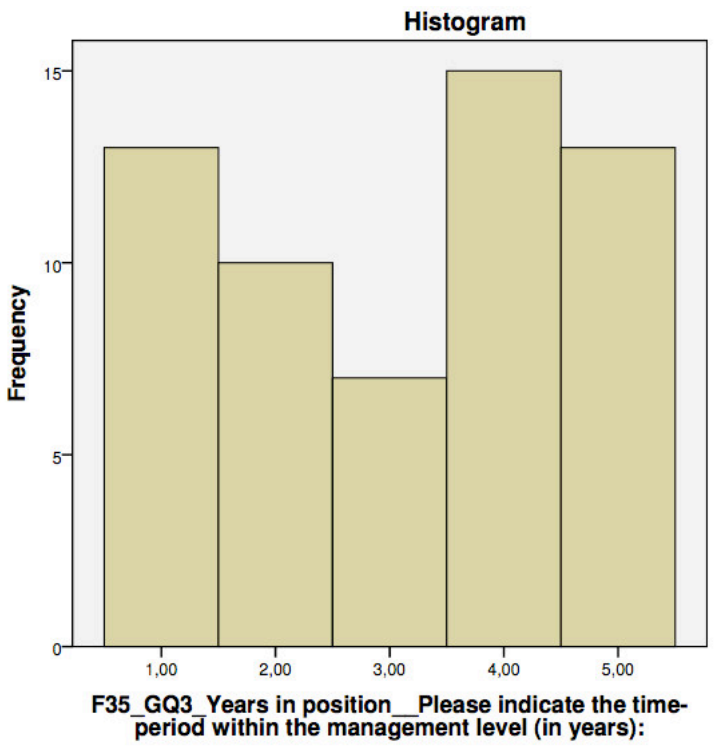


Question 34 (according to table 7):
Please indicate your management level within the company:

Answer options (according to table 7):
1 Manager (supply chain manager / purchasing manager / operations manager)
2 Supervisor (directly supervise supply chain / purchasing / operating activity)
3 Worker (supply chain / purchasing / operating activity)
4 other activity
5 not specified

Source: compiled by author. Analysis is based on 110 responses to a questionnaire survey (November 2014 to February 2015) from supply chain members of the German electricity power generation industry.

Appendix 44. **Histogram GQ2 'Position of the respondent'**

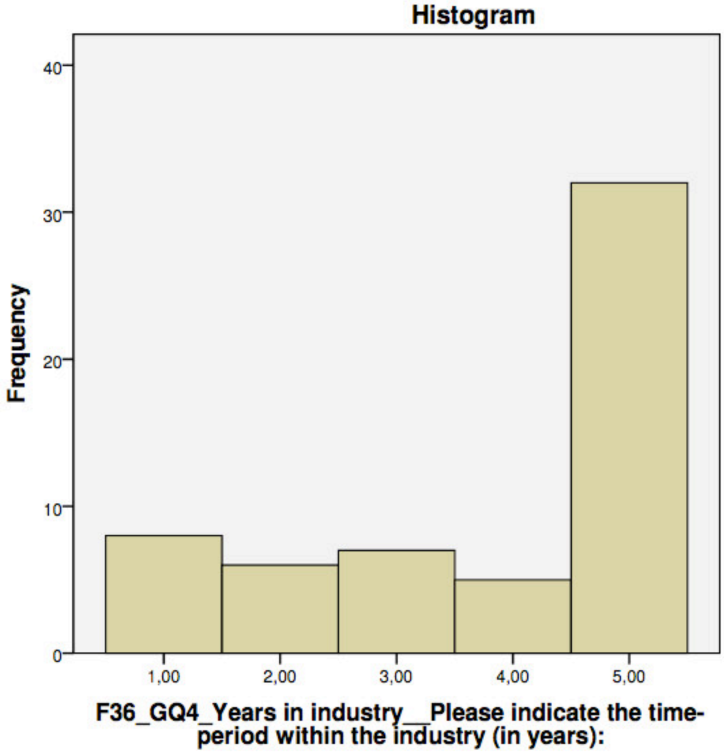


Question 35 (according to table 7):
Please indicate the time-period within the management level (in years):

Answer options (according to table 7):
1 0-1
2 2-5
3 6-10
4 11-15
5 16 and more

Source: compiled by author. Analysis is based on 110 responses to a questionnaire survey (November 2014 to February 2015) from supply chain members of the German electricity power generation industry.

Appendix 45. **Histogram GQ3 'Years in position of the respondent'**



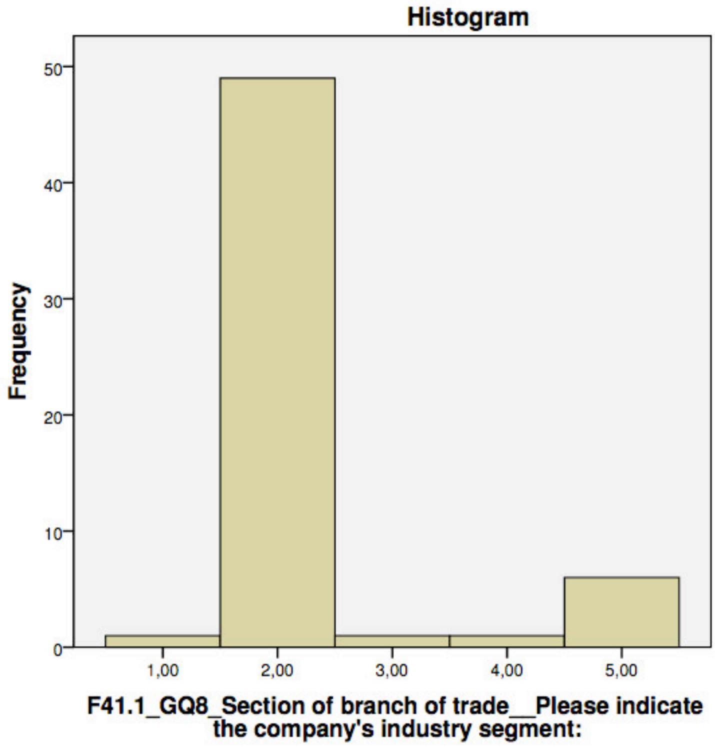
Question 36 (according to table 7):
Please indicate the time-period within the industry (in years):

Answer options (according to table 7):

1 0-1
2 2-5
3 6-10
4 11-15
5 16 and more

Source: compiled by author. Analysis is based on 110 responses to a questionnaire survey (November 2014 to February 2015) from supply chain members of the German electricity power generation industry.

Appendix 46. **Histogram GQ4 'Years in industry'**



Question 41 (according to table 7):
Please indicate the company's industry segment:
(Relevant) Sections of branches of trade according to Federal Statistical Office:

Answer options (according to table 7):

1 Mining and quarrying (Section B)
2 Manufacturing (Section C)
3 Electricity, gas, steam and air conditioning supply (Section D)
4 Water supply, sewerage, waste management and remediation activities (Section E)
5 Construction (Section F)
- Other sections:
  Note: The answer option "Other sections" contains no entries.

Source: compiled by author. Analysis is based on 110 responses to a questionnaire survey (November 2014 to February 2015) from supply chain members of the German electricity power generation industry.

Appendix 47. **Histogram GQ8 'Section of branch of trade'**