2016

Diffusion Challenges for Innovation in Technology-Intensive Industries

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http://hdl.handle.net/10026.1/9669

http://dx.doi.org/10.24382/3383
Plymouth University

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DIFFUSION CHALLENGES FOR INNOVATION IN TECHNOLOGY-INTENSIVE INDUSTRIES

by

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A thesis submitted to the University of Plymouth
in partial fulfilment for the degree of

DOCTOR OF PHILOSOPHY

Graduate School of Management

Faculty of Business

In collaboration with Universidade de São Paulo
Faculdade de Economia, Administração e Contabilidade (FEA-USP)

July 2015

DIFFUSION CHALLENGES FOR INNOVATION IN TECHNOLOGY-INTENSIVE INDUSTRIES

Jürgen Steinheber

Many innovations fail on the market. Non-adoption and slow diffusion represent a high risk for companies in technology-intensive industries when looking to innovate, develop, market and launch a new technology. Its diffusion in the market is a major challenge for marketing. The consequence of a failed market introduction can be financial and reputational loss. Diffusion of innovation research shows a short-coming of researching barriers and challenges which prevent new technologies from being successful. This research sheds some light in the diversity, importance and existence of barriers for the diffusion of innovation.

The originality of this investigation is a mixed-methods approach to explore barriers and challenges for the diffusion of innovation. An exploratory qualitative research is performed on the unique case of digital radio diffusion in Germany. Barriers evolve by this method in addition to barriers, which so far are described in a theoretical framework. These barriers are researched empirically via an international survey with close to one thousand participants representing experienced practitioners in marketing and sales positions from different industries.

Various research findings are presented. The evolving barriers are researched and show circumstances of today, such as the dominance of internet, environmental awareness or the importance of inter-industrial collaboration. Additionally, diffusion barriers from a theoretical framework are tested with empirical data. Findings are presented as evidence for diffusion barriers and their importance for the specific example of digital radio is explained. Furthermore, barriers are also generalized for different technology-intensive industries. The existence of barriers is confirmed by empirical data and patterns of variations are outlined. Validity is achieved via triangulation of methodologies and supporting literature. The findings are presented to extend the theoretical framework and to close a gap in diffusion of innovation theory.

The research contributes in very different ways to existing knowledge. Apart from the theoretical contributions, methodological and practical contributions are also made. With quantitative research, the sampling strategy for an online questionnaire considers the benefits of professional social networks on a global level to contribute empirical data to a theoretical framework. The practical contribution is directed to industry stakeholders and practitioners such as in marketing. The research findings result in a framework of barriers and supporting illustrations for technology-intensive industries. Practitioners can benefit from the illustrations for strategic decision-making in business development, product and general management, marketing and sales.

DESAFIOS PARA A DIFUSÃO DA INOVAÇÃO EM INDÚSTRIAS DE TECNOLOGIA INTENSIVAS

Jürgen Steinheber

Muitas inovações acabam por falhar no mercado. A não adoção, assim como uma vagarosa difusão da inovação no mercado, podem implicar em um alto risco para empresas que atuam em indústrias de tecnologia intensa quando tentam inovar, desenvolver, comercializar e lançar novas tecnologias. A difusão no mercado é um grande desafio para o marketing. A conseqüência de uma introdução no mercado pode ser a perda financeira e de reputação. Pesquisas relacionadas à difusão de inovação demonstram-se insuficientes ou pouco satisfatórias quanto ao estudo de barreiras e desafios que resultam na falta de sucesso na empreitada de algumas novas tecnologias. Este estudo, então, pretende lançar uma luz no que diz respeito à diversidade e existência de barreiras que se relacionam com a difusão da inovação.

O presente estudo pode ser considerado original por abordar a questão das barreiras e dos desafios para a difusão da inovação com base em uma abordagem que engloba diferentes métodos. Primeiramente, uma pesquisa qualitativa e exploratória é realizada com base em um estudo de caso único acerca da difusão do rádio digital na Alemanha. As barreiras, desenvolvido por este método, tornam-se mais perceptíveis e tratar-se-á aqui, ainda, de outras barreiras descritas na fundamentação teórica. As barreiras são exploradas por meio de pesquisa empírica realizada por meio de um survey internacional realizado com aproximadamente mil respondentes, cujas áreas de atuação eram marketing e vendas, com atuação em diferentes indústrias.

Diversos resultados serão aqui apresentados. Pesquisar-se-á a criação e/ou o desenvolvimento de barreiras, estabelecendo-se uma relação com circunstâncias atuais e cotidianas, como a dominância da internet, a consciência ambiental e a importância da colaboração interindustrial. Adicionalmente, barreiras a partir de um quadro teorico são testadas com base em dados empíricos. Os resultados são apresentados levando em consideração evidências de barreiras de difusão assim como sua relevância; para tal, utilizar-se-á também o exemplo da rádio digital. As barreiras aqui pesquisadas são generalizadas para diferentes indústrias ligadas à tecnologia intense. A existência de barreiras é confirmada por meio de dados empíricos; variações e padrões são, da mesma forma, descritos. A validade da pesquisa é obtida por meio da triangulação de metodologias e de literaturas selecionadas. Os resultados são apresentados com o intuito de ampliar o arcabouço teórico atual, fechando uma lacuna na teoria da difusão da inovação.

Esta pesquisa contribui de várias maneiras para o conhecimento existente acerca da temática aqui abordada. Além de contribuições teóricas, contribuições metodológicas e práticas são, também, realizadas. Com base em pesquisa quantitativa, a estratégia para amostragem na elaboração do questionário online considera os benefícios de redes profissionais e sociais a nível global com o intuito de unir os dados empíricos ao arcabouço teórico. A contribuição prática é direcionada a profissionais que atuam em indústrias, como em marketing. Com os resultados da pesquisa, pretende-se gerar um quadro que aponte barreiras e alguns mecanismos de apoio para indústrias de tecnologia intensa. Profissionais poderão se beneficiar com tais mecanismos de apoio durante processos de tomada de decisão no desenvolvimento de negócios, na gestão de produtos e na gestão geral, e nas áreas de marketing e vendas.

AUTHOR'S DECLARATION

At no time during the registration for the degree of Doctor of Philosophy has the author been registered for any other University award without prior agreement of the Graduate Committee.

Work submitted for this research degree at the Plymouth University has not formed part of any other degree either at Plymouth University or at another establishment. However, this research is considered as subject of a double-doctorate agreement between Plymouth University and Universidade de São Paulo.

This study was financed with own private funding. Quantitative data gathering and analysis was additionally financed by a mobility scholarship of Santander Universidades network. The effort of the latter, as well as writing up and final editing was carried out within research collaboration with Universidade de São Paulo, Faculdade de Economia, Administração e Contabilidade (FEA-USP).

Relevant scientific seminars and conferences were regularly attended at which work was often presented; external institutions were visited for consultation purposes and several papers prepared for publication.

Publications, presentations, other forms of performed work:	see final appendix
Presentation and Conferences Attended:	see final appendix
Word count of main body of thesis:	79,996

Signed ………..…………………………………

Date …………………………………………

Acknowledgements

Special thanks go to my international supervisory team, who monitored my research progress and helped with very constructive feedback over the years. Considering our mobility in this globalized world, it always felt very good to have group discussions, either in person or during video conferences.

Prof. Jonathan Lean – I would like to express a very special appreciation for your work. With the many conversations about my research progress, the way of data gathering or regarding transatlantic research cooperation, I have claimed much of your time. Thank you very much for everything you helped me with. You were always there and you always assisted me with very constructive and valuable feedback.

Prof. Dr. Wolfgang Döhl – thank you very much for the history I can share with you, both as student and visiting lecturer at Munich University of Applied Science, Germany. I could gain a lot of valuable experience. As my director of studies you gave me important guidelines for the research and kept me motivated until its last steps. I would also take the opportunity to acknowledge the great work you do for Munich University of Applied Science.

Prof. Jonathan Moizer – it was very interesting to learn from your feedback and questions, especially regarding the methodology of this research. I appreciate your help and honest opinion. Thank you very much.

Prof. Ary Plonski - I am very grateful and would like to thank you for your mentorship and the excellent discussions during my research stay at Universidade do São Paulo, Brasil in 2013 and 2014. An additional acknowledgement goes to the Santander Scholarship program supporting my research stay in Brasil.

Prof. Natalia Villa - thank your very much for your guidance with researching influencing factors of a model and the creation of according variables during my time at Universitat de Valencia, Spain in 2012.

Dear Mum and Dad, I am very grateful for your care and trust in me, and I thank you further for your constant interest and positive stimulation. Particularly, I am also grateful for the childhood that you gave me in such a natural and protected environment. Dear Thomas, thank you for encouraging me during difficult times and situations. All other family members and friends; thank you for your interest and support.

Dear Anjali – you are amazing! We faced some challenges before we could finally live in the same place, but during these times you kept me motivated for this research. Your understanding, advice, intellectual spirit and general support are difficult to describe in words. You were the brightest spot on my horizon. I am enjoying life with you and I am looking forward to many happy and exciting years together!

I would like to acknowledge my interview partners during the case study research and the many respondents of the survey. They provided valuable information on the research of barriers for the diffusion of innovation. Indirect incentives were announced for participating in the survey. At the time of submission, I have donated about two thirds of the 726 incentives for the target group. I decided to give donations to UNICEF's program for education, because education is a basic human right and everyone should be entitled to it. I as an academic researcher, you as a reader and the practitioners referred to in this thesis are fortunate to have an easy access to education while others don't. We should be very grateful for this!

"Education is the most powerful weapon which you can use to change the world."

(Nelson Mandela. 1918-2013)

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List of Acronyms

DAB	Digital Audio Broadcasting
FM	Frequency Modulation
ISO	International Organization of Standardization
IT	Information Technology
R&D	Research & Development
ROI	Return-on-Investment
SME	Small and Medium-sized Enterprises
SPSS	Statistical Product and Service Solutions
UN	United Nations
US	United States (of America)
WOM	Word-of-Mouth

“Just as energy is the basis of life itself, and ideas the source of innovation, so is innovation the vital spark of all human change, improvement and progress.”

(Ted Levitt, 1925-2006)

1. Introduction and Significance

This chapter introduces the research and its origin, stating a number of research questions, which lead to research objectives. It demonstrates the need of the research and defines the aims and objectives. A presentation of the thesis structure is included to introduce the various aspects covered throughout the chapters of this study.

1.1 Introduction of the research

1.1.1 Problems and risks with introducing new technology

The use and emergence of innovation and new technologies dominates both our businesses and private lives. However, a large number of innovations fail on the market. The consequence for a company is a low return-on-investment (ROI) or a loss of investment and reputation (Bayus et al., 2003; Hess, 2009). Thus, the introduction of an innovation represents a certain risk associated with an unsuccessful diffusion.

Among the most famous failures in the first decade of the 21st century we find a diversity of technological products in consumer electronics (Carnoy, 2010; Davies, 2011). Other examples are DVD recorders from 1999, robot pets such as Aibo by Sony from 1999 but stopped in 2006, first tablets by Compaq from 2001 or HD radio receiver products with new sound broadcasting technology from 2003 (Carnoy, 2010).

There are some famous examples. Sony's Betamax was introduced in 1975, one year before JVC's VHS. As Sony decided not to allow other manufacturers to sublicense Betamax technology, VHS became dominating in the market for video tapes. Introduced in 1983, Apple's Lisa is regarded as a similar failure (West, 2005). Although it is seen as important innovation in history due to its combination of mouse and graphical user interface, it flopped on the market (West, 2005; Davies, 2011).

Examples can also be found in other industries such as the automotive industry (Davies, 2011). The automobile history of the last 30 years also shows that not every innovation focusing on energy consumption was successful on the market. Neither engines with low fuel consumption such as in AUDI's A2 or VW's 3L-Lupo were success-stories (May, 2009a) nor was the start-stop automatic a break-through on the market. After its introduction by Toyota during the first oil crisis, start-stop systems were re-introduced during the second oil crisis by the Volkswagen group about 25 years ago (Dunham, 1974; Bertel, 2013; Grund, 2013). It did not have a lot of market success back then (May, 2009b, Bertel, 2013; Grund, 2013) either.

Going back in time, in each decade there have been high numbers of products and technologies failing on the market in different industries (Berth, 1993; Wind & Mahajan, 1997; Andrew & Sirkin, 2003; Stone, 2008). In high-tech industries there is a tendency for higher dynamics in innovativeness as product cycles get shorter (Pfeiffer & Weiss, 1990; Goktan & Miles, 2011; Chen et al., 2012). Technology-intensive products tend to get very complex as innovations bring up a lot of different configurations by digitalization and software defined features. With more technologies and shorter life cycles, the rate of market failures is very high (Chen et al., 2012). With so many examples, questions that arise are, why a new technology is not accepted by the market and what the consequences are for the companies.

The rate of failing innovations is relatively high (Berth, 1993; Bessant & Tidd, 2007). According to empirical research, Berth (1993) explains that more than 70% of all products are eliminated by the market itself by non-adoption. According to Berth (1993) almost 50% of the products remaining in the market are in a loss area and only about 20% of the remaining products are successful. Similar results can be found in literature over several decades (Crawford, 1979; Booz et al., 1982; Ram & Sheth, 1989; Berth, 1993; Wind & Mahajan, 1997; Andrew & Sirkin, 2003; Stone, 2008, Hess, 2009) and the failure rate seems to remain high (Ortt & Smits, 2006). However, research results on failure rates seem not to be consistent and vary between 50% and 90% across industries (Hess, 2009). The products that have been the subject of published research also represent several types of innovation (sustaining and disruptive).

For companies, non-adoption and a slow diffusion of a technology implies having made wrong investment decisions with the consequence of reputation loss (Hess, 2009). Considering high failure rates of innovation, companies have to face high risks in developing and launching new products with new technologies (Ortt & Smits, 2006; Hess, 2009). Decision-making in business and marketing strategy towards the development of innovations needs to consider those risks. Risk evaluation should consider challenges and barriers as potential reasons for market failures. A business and marketing strategy to overcome potential barriers should be developed significantly before the actual launch of a product innovation (Montaguti et al., 2002; Moore, 2006; Hess, 2009). Marketing technical products means that potential adopters have to be convinced concerning its innovativeness, its technology, its utility and usability, but it also means that potential barriers should be considered when important decisions are being made regarding both the development and the marketing of new technology.

Different concepts and frameworks exist about influencing factors, such as the work of Rogers (1962) describing important attributes for innovation. However, research lacks a focus on diffusion barriers. The management of diffusion barriers, when new technologies are introduced, is aimed for in this research focusing on manufactured goods which incorporate new high-technology.

1.1.2 Improvements for existing frameworks and concepts from literature

Considering high failure rates for innovation over various past decades, it is very important for high-tech companies of different industries to take into account potential barriers (Hess, 2009). Apart from taking advantage of facilitators for successful innovations, a consciousness of potential existing barriers to overcome is important for decision-making for a successful strategy.

Among several explanations why technologies fail after introduction, some are based on the investigations of Moore (1991), who adapted Rogers' diffusions of innovations model (1962). Focusing on effects of diffusion as communication within a social group or environment (see also Robinson, 2009), the author describes a critical period of time in sales, introduced as a ‘chasm’ before the early majority starts to gain interest in the technologically new product. Apart from that, Moore also describes other critical periods as well. Moore focused on problems and dangers that growing high-tech IT companies of the late Nineties have to face when marketing their technologies. The illustrated problem might also occur in different types of industries (Gladwell, 2000).

In contrast to Moore, investigations of Hess (2009) and Ram and Seth (1989) illustrate barriers for individual adoption decisions. Barriers are presented which may prevent individuals from deciding to adopt a new product containing a new technology. Unfortunately, this concept does not consider effects from a macroeconomic point of view such as a whole market or industry.

While the investigations of Hess (2009) focus on individual decision-making and Moore (1991) on the diffusion problem of the IT industry, a more recent and general research is performed by MacVaugh and Schiavone (2010). They have realised that practitioners may need more guidance when evaluating the success of a certain innovation and the adoption of a new technology. Their investigations are based on Rogers (1995) and aim to give an overview of potential barriers for the diffusion of innovation. Nevertheless, MacVaugh and Schiavone’s (2010) model of limiting factors of the diffusion of innovation (referred to as LF-model) is purely based on theoretical research (Table A-1). Its barriers are neither weighted for importance nor cross-linked.

A useful framework is important for practitioners. However, existing literature of barriers shows gaps and limitations regarding their content and their methodology. The LF-model appears to be a good basis but illustrates a number of limitations, such as a lack of empirical data. Contemporary aspects such as environmental awareness and a need of adaptability also seem not to be described as diffusion barriers in literature. This study contributes with needed empirical research on variations in the importance and relevance of barriers. Additionally, a suitable framework of barriers in the context of their industry is provided to reduce risks with introducing a new technology.

1.2 Aim and Areas of the research

1.2.1 Overall aim of the research

Diffusion of innovation research displays a shortcoming of diffusion barriers (Ram & Sheth, 1989; Nutley et al., 2002; Hess, 2009). Existing literature about diffusion barriers show gaps in methodology (lack of empirical data), theory (missing macro-level focus) and industrial context. Therefore, the research aim of this thesis is to explain the potential risks for the adoption of a new technology. This investigation focuses on diffusion barriers regarding their existence and importance and contextual variations.

The overall aim of this research is to explore the importance and relevance of barriers for diffusion of innovation in medium high-tech and high-tech industries. The thesis highlights important barriers which should be considered for decision-making in strategy and marketing with new technologies/products (Hess, 2009). The applicability of theoretical models is illustrated. Regarding the suitable LF-model, suggestions for additional barriers are given concerning their importance and existence.

Real-world case studies and a survey contribute to research those aspects empirically. The research can show possible dependencies among barriers and can illustrate the need of action to drive an innovative technology or product to its market success.

The outcomes of this research should act as an additional guideline for applying the theoretical LF-model for strategic decision-making in product management, business development and in marketing related to marketing strategy and its implementation.

1.2.2 Potential research areas and main research questions

One of the research’s goals is to provide a guideline to both, organizations and practitioners in order to face, evaluate and manage the risk of diffusion barriers for new technologies. In order to put the theories into practice, several questions arose concerning marketing and strategy decisions with current and future technologies. The questions are detailed next in order to use them as the basis for research objectives.

As the concepts and frameworks with diffusion barriers for innovation refer to theories partly from several decades ago, circumstances may have changed. Therefore, an important question is whether the barriers are still the same compared to past decades. To answer this question, it would be beneficial to explore the diversity of barriers of past decades together with critical aspects for technologies nowadays regarding their relevance for the according industries. Results may give the possibility of preparing potential future market environments and technology introductions.

Concerning the existence of barriers for the current decade, additional aspects should be considered. Changes in environmental awareness, information access and constraints of new generations may play an important role. Both communicating product features and aspects of the production process regarding their environmentally-friendliness are interesting challenges for marketing, which may influence diffusion. Another example of the change in society is the dominance of internet and the different behaviour shown by new generations (digital natives). This introduces the need for innovations to provide a higher adaptability and flexibility in order to cater for the needs in different generations or regions. Therefore another important area for research can be to clarify whether these aspects can mean additional difficulties to the diffusion of an innovation.

Several concepts and frameworks exist to describe different areas of barriers for the diffusion of innovation. The concept of the chasm may also be regarded as such. A comparison can be made between different concepts in order to present a suitable framework of barriers to practitioners.

The theories of Moore focus on IT as high-tech industry during the late nineties (Moore, 1991). The LF-model includes barriers from investigations in different industries. For companies in different industries it is very important to take into account diffusion barriers relevant for their context. It would also be interesting to draw parallels to the situation of different types of high-tech industries. Therefore, the question which arises is whether the importance of barriers is comparable under different circumstances.

The introduction of research areas guides us to the primary research questions. Taking into account various aspects of importance, the following research questions were pursued:

- Which are the barriers for diffusion of innovation during the current period?
- Do changed environmental awareness and the need for adaptability imply the existence of different diffusion barriers compared to other diffusion of innovation research?
- Do models or frameworks of barriers correlate? (e.g. chasm concept with other frameworks)
- Are barriers existing in one industry comparable to barriers existing in other industries?

A table (see Table B-1) helps to display how these questions lead to research objectives coming about from literature and how they are met. Referring to research objectives the stated questions arise in the following sections. Based on the described research areas and questions, the next section will illustrate which objectives can be derived from the wide and open possibilities for researching the diffusion of innovation.

1.3 Main objectives of the research

1.3.1 Objective 1 – Identifying barriers for the diffusion of innovation

Following one of the main research questions, finding out which barriers are critical for preventing innovations from diffusion, from crossing the chasm and from market success, several questions arise. Do diffusion challenges and non-adoption occur due to various barriers or to one single barrier? Which barriers have been important for innovations in the last decades? Are there recent investigations updating the literature explaining barriers? Which are barriers that can be overcome easily in order to boost innovations in their diffusion process? Focusing on the change of the century, even more questions can be raised. Is green argumentation facilitating diffusion? What about the perception of energy-friendly technology? How different are the needs of the current generation and which impact does it have?

One main objective based on these questions is to find out which contemporary barriers prevent today's innovation from its diffusion and whether they are part of MacVaugh's and Schiavone's (2010) results of investigation. Based on investigations of the last decades and their outcomes, an overview can be given outlining barriers that limit an innovation from diffusing and their inter-relation in a structured approach. However, published empirical researches might not include critical contemporary barriers, which are of recent importance.

A significant and important dimension of this research objective is a consciousness of barriers among practitioners in marketing and product management regarding their existence and their relevance for a successful diffusion of innovation. Illustrating models with diffusion barriers from literature may be extended by newly discovered barriers.

1.3.2 Objective 2 – Identifying variations & patterns of diffusion barriers

As concepts refer to barriers with a focus on specific industries (e.g. Moore, 2006), it can be questioned whether these circumstances vary for different high-tech industries. This brings up more questions.

Are barriers comparable within different industries? Are there differences between regions and economies? Are there interdependencies among barriers? What about the perception of such barriers concerning different technologies? Are there differences between business-to-business (B2B) and business-to-consumer (B2C) industries?

An objective to address portions of the questions raised is to explore variations and patterns as important information for practitioners to help marketing practitioners to prepare suitable instruments. The main method of addressing this objective is a survey directed to experts in technology marketing and product management of different industries in order to research patterns and interdependencies of barriers for the diffusion of innovation.

This research objective is subject for investigating a generalization of diffusion barriers and their different levels of importance and relevance. Variations, interdependencies and communalities between barriers for diffusion of innovation are researched.

1.3.3 Objective 3 – Suggesting a framework of barriers for practitioners

Many questions arise from the previously mentioned areas of research and objectives. Results of the research may be used for further business simulation and models for predicting the diffusion of an innovation (Bass, 1969), but the most important impact would rather be for practitioners. An applicable model for practice such as the one of MacVaugh and Schiavone (2010) may be of interest for practitioners. Several questions and doubts exist when decisions have to be made in business development, strategy, product management and marketing (MacVaugh & Schiavone, 2010). This target group needs guidance taking into account the existence of barriers for diffusion of innovation.

The mentioned practitioners may raise a diversity of questions: Are there significant barriers waiting in our market? Do we face a potential chasm situation? Which barriers and related aspects are important to make our technology successful? Which barriers do we have to check when writing a new business plan? Can we be successful although there are barriers endangering diffusion of innovation? When, how and to whom should we communicate a new-generation of technology? How can we launch new technologies under circumstances like a higher environmental awareness or changed expectations and behaviours among a new generation in our society?

Having a look at the mentioned questions, contributions to knowledge can be established regarding diffusion barriers in the field of technology marketing (MacVaugh & Schiavone, 2010). This research objective is to provide a framework of barriers for practitioners in order to assist with decision-making for the development of a new technology or to prepare marketing and sales methods in order to overcome diffusion barriers. Potential improvements to existing models such as the LF-model will be outlined.

To achieve this objective, empirical research via a survey will be used to provide an idea to practitioners which barriers are more important and which less. Thus, recommendations can be given on applying known concepts like the one of MacVaugh and Schiavone (2010) in a tailored way. Business development, product and marketing managers are the target group with a strong interest in successfully preparing for and managing potentially existing barriers for the diffusion of a technology in their industry and market context. This objective contributes essentially to the overall purpose of such a framework, which is assisting practitioners.

1.4 Integration of objectives to a broad research purpose and approach

In order to illustrate and summarize the broad research purpose, it is important to define the type of technologies and innovations, whose diffusion is addressed in the research. In contrast to pure software, this study focuses on manufactured high-tech goods incorporating a dominating technology as innovation.

Besides disruptive innovation, the primary focus of this research is on sustaining innovation (Christensen, 1997) whose basic application has already been in the market as this is the most frequent type of innovation according to Christensen. For those kinds of innovation, an objective is to identify barriers which might prevent or hinder its diffusion, visualised in the right part of the following illustration.

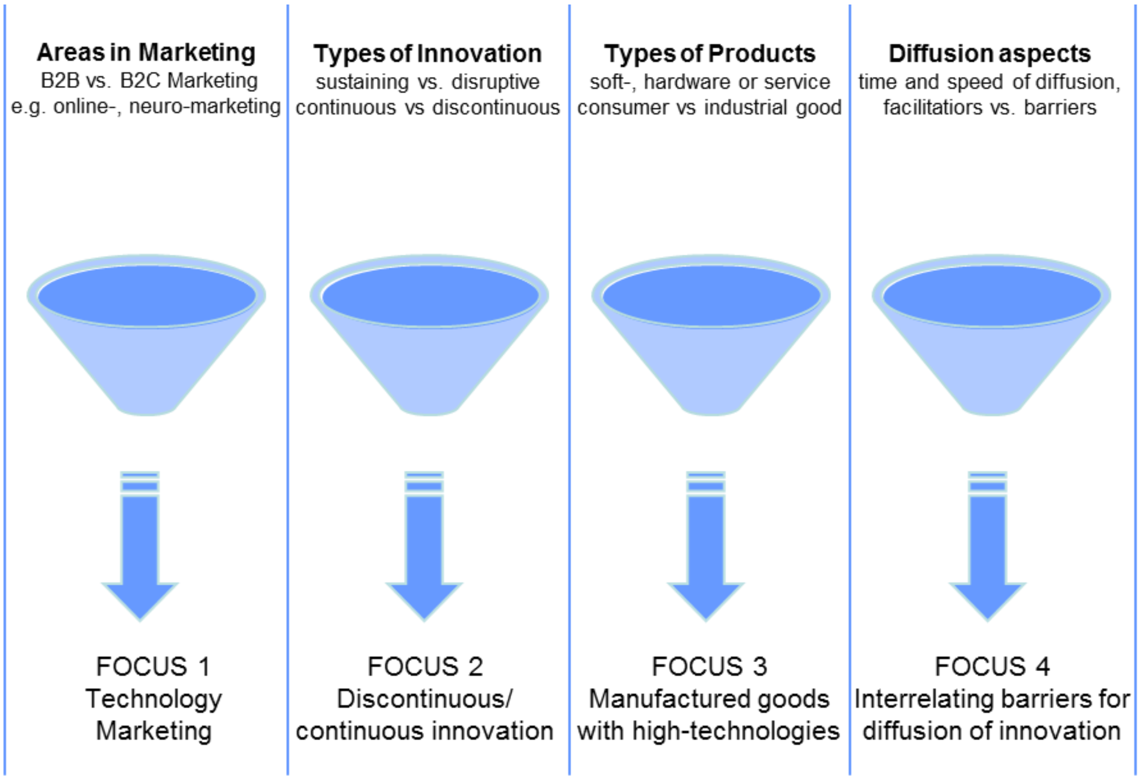


Figure 1-1 – Specifying research areas and related focus

With the illustration of the thesis's focus in the area of innovation research, three introduced objectives are followed. The first objective of identifying barriers is shown in the left part of the subsequent illustration (see Figure 1-2). With a set of potential barriers based on those identified by MacVaugh and Schiavone (2010) for diffusion of innovations and their importance and relevance, variations and patterns are researched. The identification of patterns to develop a framework for practitioners is also a second main objective of the research and already leads to the objective of putting theory into practice.

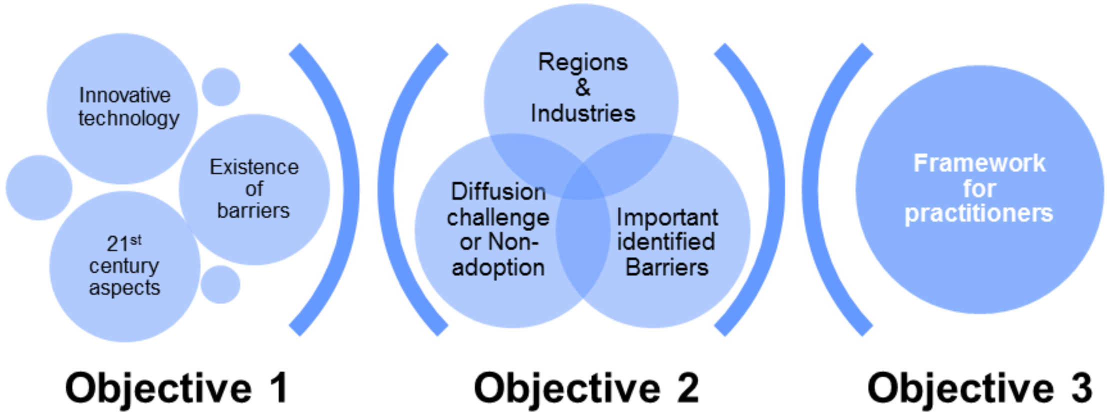


Figure 1-2 – Integration of research objectives

The development of a tailored framework suitable for the context of practitioners is a third objective of this research. Practitioners with a responsibility related to products and their technology, related to marketing strategy, related to its business cases, related to sales number and related to strategic decision-making are addressed.

In order to address the research objectives, the main purpose is an exploratory research of the significance of barriers for innovative technologies in specific industrial environments. By researching barriers with initial case study research containing expert interviews and researching patterns of cross-linked barriers via a survey, a tailored framework for practitioners can be established. With the help of the framework, awareness towards the existence of diffusion barriers regarding developing, marketing, communicating and selling technology can be created. During the course of the research, the different objectives are followed. The course of the research is summarized in the following section.

1.5 Structured outline of the thesis

The thesis is structured in a sequential order as well as an order depending on depth in abstraction as follows. The chapters and sections are oriented towards basic questions, illustrated in the following figure:

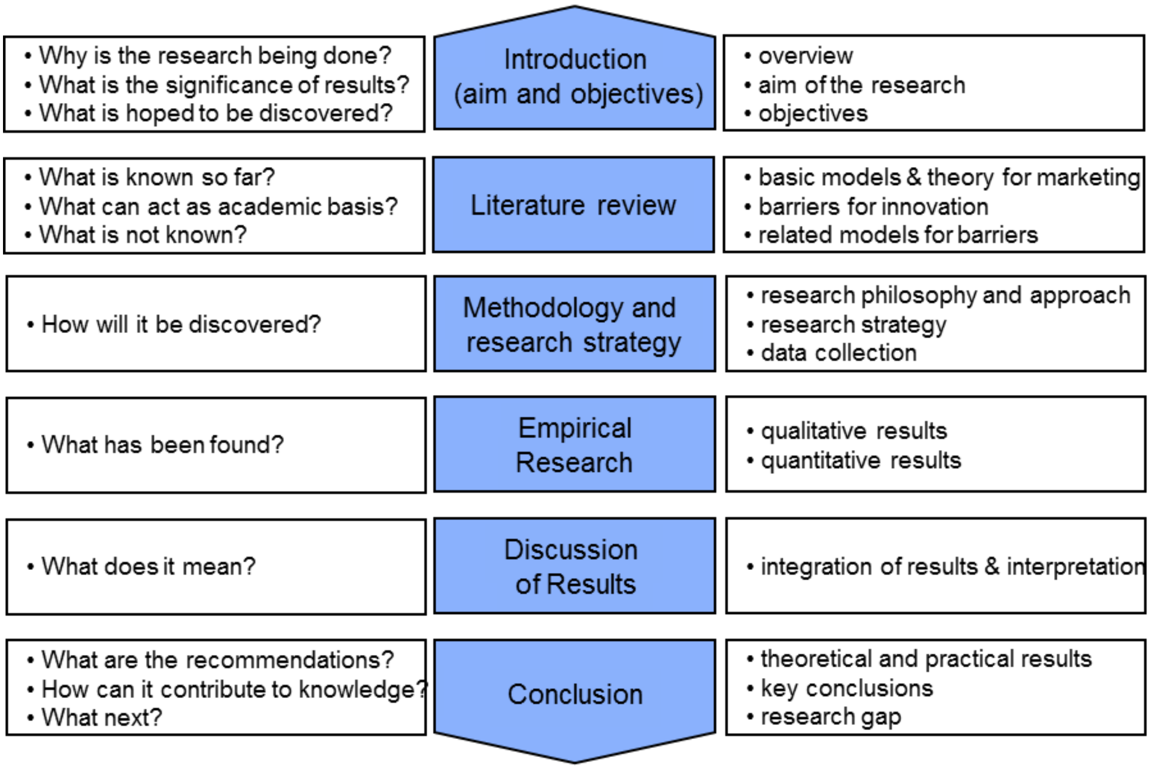


Figure 1-3 – Structural elements of the thesis

Why this investigation is done and what potential results can mean is explained in the first chapter with the definition of research objectives. The chapter describes the originality of the research regarding the needs of further empirical research supporting the so far existing theoretical data.

After the introduction chapter, a literature review is outlined, focusing on basic models for marketing and diffusion of innovation research and on literature related to the research discipline of concepts and frameworks of barriers.

A further chapter is dedicated especially to the explanation of the methodology regarding both qualitative and quantitative aspects and its strategy as this is of essential importance in approaching the research objectives. Methodological contributions are made as part of the mixed-methods research approach and are explained in this chapter.

A fourth chapter illustrates what has been found regarding qualitative and quantitative research results. The presentation of results of the empirical research consisting of various elements leads to a discussion chapter. A section is spent to integrate the results of the mixed methods.

What the results mean is discussed separately in a fifth chapter. The integration of results and their meaning is discussed in depth. Practitioners in industries can benefit from the illustrations presented in the chapter.

The research about diffusion challenges of innovation and its research strategy contributes in very different ways to existing knowledge. A final chapter presents conclusions and the discussion of the methodological, theoretical and practical contribution to knowledge, its limitation and areas of further research.

1.6 Concluding chapter summary

This chapter has discussed the failing of innovations and the need of overcoming diffusion barriers for innovation is explained. As there are various sources in the literature about problems and barriers for the diffusion of innovation, some researchers have aimed for defining usable models. Having researched both, theoretically and empirically, MacVaugh and Schiavone (2010) provide a relatively compound integration of barriers into a framework for practitioners, the LF-model.

As the LF-model is based on theoretical research of the previous decades and as its various aspects are not weighted concerning their importance or relevance, two related research objectives are defined to verify barriers, their importance and variations supported by empirical data. Based on empirical data, this research aims to develop a tailored framework, e.g. as modification or extension of the LF-model, to aid decision-making in strategy, marketing and sales. The integration of the research objectives to a broad research purpose is illustrated for structuring the thesis.

Summarizing this initial chapter, the research area is described regarding gaps in knowledge to which the thesis can contribute by empirical data gathering. The need of a barrier framework for the practitioners target group of different industries based on empirical data is introduced. The following chapter presents diffusion of innovation literature and literature about diffusion barriers.

2. Critical Literature Review

This chapter outlines which literature pertinent to the study and illustrates where there are gaps in theoretical and empirical research to justify and explain the main aim of this thesis. One body of knowledge is presented concerning basic definitions and models referred to during the course of the research. A second body of knowledge sums up findings and limits of diffusion of innovation research. Literature for the research discipline is reviewed regarding barriers and challenges for the diffusion of innovation.

2.1 Background literature: Basic definitions and models referred to

2.1.1 Definitions for innovation

To be considered as ‘innovation’, the use of a new idea has to be novel (Schumpeter, 1939). Some publications, which define ‘innovation’, take into account that within a certain geographic area less than ten per cent of the population knows about the new idea (Bodenstein, 1971). Kaas (1973) suggests seeing an idea as innovative as long as it has not been applied or adopted. Rogers, originally referring to studies about seeds (Rogers, 1962), also is very general, describing innovation as “… an idea, practice, or object that is perceived as new by an individual or unit of adoption” (Rogers, 2003, p. 15). In contrast to measurable definitions, the individual perception rather determines the innovativeness of a new idea, as Böcker and Gierl (1988) additionally suggest.

Another very early and general definition is given by Thompson who explains innovation as the process of generating, accepting and implementing “… new ideas, processes, products or services …” (Thompson, 1965, p. 2). Distinguishing between a technical invention and an economic innovation is the basic idea of Joseph Schumpeter’s (1939) investigations. For Schumpeter, innovation could either be the “…launching of a new product or of new forms of organization, the accomplishment of a merger or the opening of new markets” (Schumpeter, 1939, p. 88).

Damanpour and Evan (1984) distinguish between technical innovation and administrative innovation. A more complex definition is later given by Damanpour (1996) with the focus on associated changes for the environment. The according publication contains the definition of various types of innovation such as a "… new product or service, new process technology, new organization structure or administrative systems, or new plans or programmes pertaining to organization members" (Damanpour, 1996, p. 694).

McKeown (2008) distinguishes between changes in a radical or incremental way concerning the way of thinking, things, processes and services. Arguing that innovation is not only a product or service ready to use, Baregheh, Rowley and Sambrook's (2009) definition combines elements of previous definitions:

„Innovation is the multi-stage process whereby organizations transform ideas into new/improved products, services or processes, in order to advance, compete and differentiate themselves successfully in their marketplace."

(Baregheh et al., 2009, p. 1334)

As the objectives of this work focus on new technologies in manufactured products of high-tech industries, innovation in the form of a new technology is seen as its subject. Therefore, the next section focuses on types of innovation in order to differentiate technological innovation.

2.1.2 Types of technological innovation

Clayton M. Christensen investigated benefits of innovation rather on the business case approach (Christensen, 1997) focusing on disruptive technology aspects (Afuah, 2009) with the potential of radical changes (Bower & Christensen, 1995). Doing so, the author tried to define different types of innovation researching disk drive market dynamics, which years ago already had to face a rapid change considering the capacity per area of disk. The author's arguments (Christensen, 1997, p. 3) for that kind of industry got popular:

"… those who study genetics avoid studying humans because new generations come along only every thirty years or so, it takes a long time to understand the cause and effect of any changes. Instead, they study fruit flies, because they are conceived, born, mature and die all within a single day. If you want to understand why something happens in business, study the disk drive industry. Those companies are the closest things to fruit flies that the business world will ever see".

(Christensen, 1997, p. 3)

The wording 'disruptive innovation' (Christensen & Raynor, 2003) refers to innovation with a high potential of creating a completely new market and new customer values. This can be very disruptive to an existing market as an existing technology might be substituted.

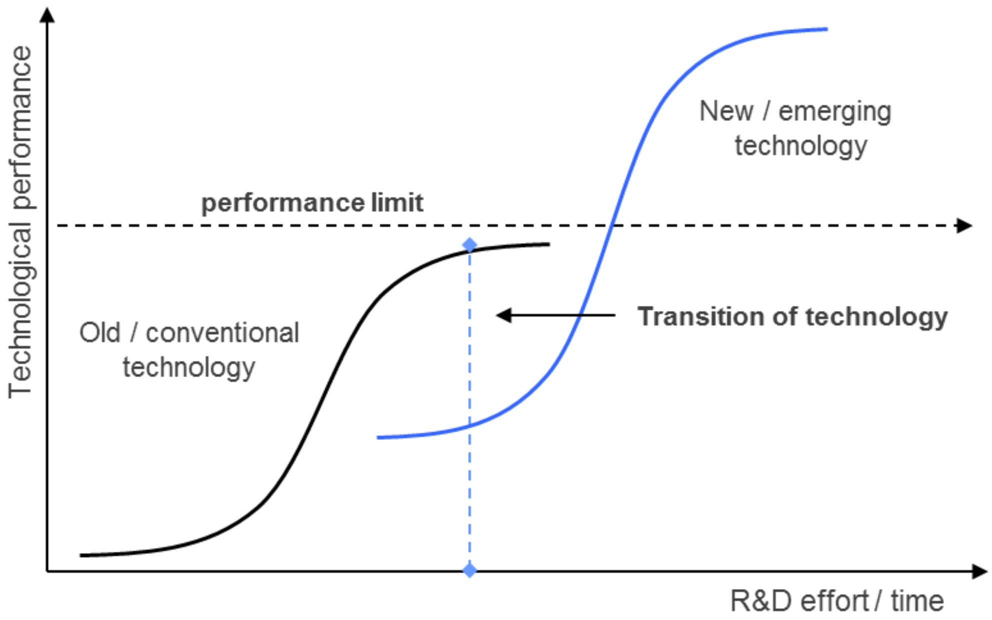
Usually this kind of innovation improves a product in a way a market does not expect by initially focusing on a completely different type of market. Chan and Mauborgne (2005) refer to this as strategy for 'blue ocean' before finding its way to traditional markets. Christensen (1997, p. 15) explains these phenomena as follows:

"Generally, disruptive innovations were technologically straightforward, consisting of off-the-shelf components put together in a product architecture that was often simpler than prior approaches. They offered less of what customers in established markets wanted and so could rarely be initially employed there. They offered a different package of attributes valued only in emerging markets remote from, and unimportant to, the mainstream."

(Christensen, 1997, p. 15)

Innovations not creating new markets and remaining in existing market environments are called 'sustaining innovations'. Existing products are extended with additional features and improved to have an enhanced performance (Sahal, 1981). Sustaining innovations may be seen in different categories (Anderson & Tushman, 1990; Moore, 1991; Rogers & Hartman, 2005), which are discontinuous innovations or continuous innovations. Moore (2006) explains discontinuous innovation as change-sensitive as they are "… products that require us to change our current mode of behaviour or to modify other products and services we rely on" (Moore, 2006, p. 10) whereas continuous innovations are results of a normal upgrading without having to change behaviour.

The growth curve or the s-curve (Mansfield, 1961; Twiss & Goodridge, 1989) can be helpful to describe different sustaining technological innovations referring to the potentials of technological performance. Milling and Maier (1996) regard the s-curve concept as an effective tool for explaining the development and transition of a new technology. At the end of a technology's s-curve it is difficult to improve the performance (Sahal, 1981; Christensen, 1997), as it gets more and more expensive and the degree of improvement gets smaller, as the following figure illustrates.



Source: Adapted for this research from Miles and Maier (1996)

Figure 2-1 – Performance limit and technology substitution by sustaining innovation

As the black s-curve demonstrates, an innovation can show continuous improvement with increased technological performance. However, alternate and superior technologies with room for higher energy efficiencies may be explored, illustrated by the blue curve. With the development course of a new technology the increase in performance over time is very high in its early stage, leading to discontinuity of an old technology with lower performance. The old technology would be substituted by a new technology (Sahal, 1981; Davis, 1989), for example a discontinuous innovation. Examples can widely be found for a digitalization of applications, previously dominated by analogue technology, e.g. photography (Gehani, 1998; Steffens & Kaya, 2009).

According to Christensen (1997, p. xviii), discontinuous innovations may also be seen as ‘transformational’ or ‘revolutionary’. Discontinuous innovations are “…technological breakthroughs that help companies rewrite industry rules” (Kaplan, 1999, pp. 16). In contrast to that, continuous innovations are referring to a process of product evolution. Summing up different aspects on how an innovation can be described and classified, the following table gives three different types of technological innovation, which will be used during the course of the research.

Type	Sustaining	Description
Disruptive	Non-sustaining	An innovation that creates a new market by applying a different set of values, which ultimately and unexpectedly overtakes an existing market.
Continuous (evolutionary)	Sustaining	An innovation that improves a product in an existing market in ways that customers are expecting e.g. having the same using behaviour.
Discontinuous (revolutionary)	Sustaining	An innovation that is unexpected, but nevertheless does not affect existing markets. There might be unexpected aspects, e.g. a changed using behaviour.

Table 2-1 – Types of technological innovation

Comparing sustaining innovations with disruptive innovation, it has to be mentioned that traditional and well-working companies within an existing market environment might suffer in case they stick to sustaining innovation if the market is penetrated with disruptive innovations. Christensen gives an example with scanning technology. (Christensen, 1997)

A lot of innovations fail, of which some are disruptive and some are sustaining. Many innovations, especially industrial goods, are sustaining. However, the focus of this research is on factors for the success or failing of sustaining innovations (replacing old technologies) and disruptive innovations (introducing new technologies). Different success factors may already be identified during the origination process of innovation.

2.1.3 The innovation process

The basic model of Schumpeter (1939) consists of three phases for the innovation process, which are invention, innovation and diffusion/imitation. After innovation, in a diffusion or imitation process the innovation becomes known and penetrates its market. In contrast to such a linear model (Langrish et al., 1972), Milling and Maier (1996) explain incremental invention. Inventional work should be seen as a continuous growth process of technological knowledge (Rosenberg, 1976).

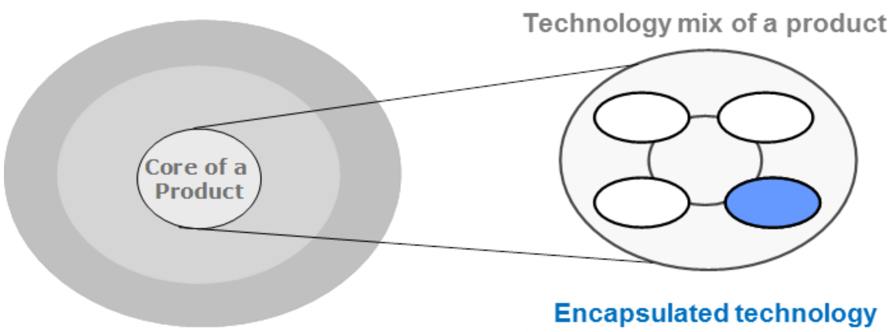
Van de Ven et al. (2000) focus on four different steps with the idea, its design, its implementation and a stage, when the innovation is accepted. The latter may be its incorporation into a product or system but can also be a successful diffusion. According to them, after a successful diffusion, the technology is no longer seen as innovation.

According to Rowley (2011), the innovation process varies as there are different types of innovation, different market environments with a different need for speed and different organizational cultures. Therefore, the author suggests a multi-stage model referring to the one of Kotler (2003) focusing on the commercial context of goods. The stages are idea generation and screening, concept development and testing, market strategy development, business analysis, product development, market testing and commercialization. Typically, diffusion takes places among the targeted customer group with the number of adoptions during the stage of commercialization.

Almost all stages by Kotler (2003) and Rowley (2011) contain possibilities in which important decisions can be made evaluating relevant potential barriers for the diffusion of innovation and thus its market success. As barriers occur during the diffusion of innovation, this investigation follows the objective to provide a suitable framework to increase related consciousness a priori. Applied models like the concept of product life cycle can illustrate when such a framework can be applied.

2.1.4 Decision-making during the integrated product life cycle

Most technical products consist of different components or devices representing different technologies. This is referred to as technology mix (Döhl, 2006). According to Capon and Glazer (1987), the decision for a proper set of technologies as technology mix at the right time is challenging. A product can encapsulate a mix of interacting technologies (Pagell, 1991). The following graphic (Figure 2-2) illustrates how an innovative product can consist of several innovative technologies.



Source: Modified from Steinheber and Döhl (2012)

Figure 2-2 – Product innovation encapsulating technological innovation

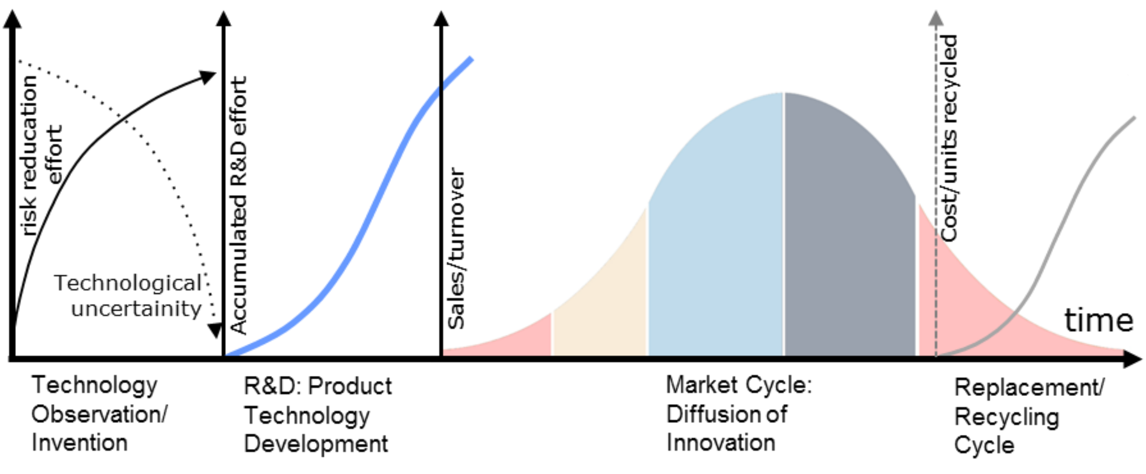
For the sake of simplicity during the course of this research, it is assumed that an innovation can either be a technology or a product, consisting of one primarily dominating technology. This technology can be subject to be substituted by another technology (Steinheber & Döhl, 2012) for sustaining innovations as illustrated in section 2.1.2.

Referring to a product, Steinheber and Döhl (2012) point out that each embedded technology is subject to the dynamic course of technical progress at a different speed and different performance level. But technology decisions need to be made before research and development (R&D) and long before the product life cycle.

The concept of product life cycle (Day, 1981) is often applied. It describes a typical development of turnover during a product's life in the phases of market introduction, growth, maturity and saturation/decline. It is referred to both empirically and theoretically in various investigations, e.g. by Brockhoff (1967), Day (1981), Midgley (1981), Easingwood (1988) and Bass (1995). The life cycle of a product describes its existence from the cradle to the grave. Besides decisions about technology usage, many crucial strategic and marketing decisions have also to be made before launching a product.

Marketing technological innovation calls for active technology management. According to Pfeiffer and Weiss (1990), Pfeiffer et al. (1991) and Döhl (2006), the integration of phases for design and development of such an innovation extends the pure market life cycle. Important decisions (Ritzen & Bewko, 2001; Heijungs, 1998) for technologies, the supply of material and components (Friedman, 2008) or the production process must be made long before a potential diffusion can take place.

A variety of literature provides decision frameworks for the appraisal of future success (e.g. the scorecards of Kerka et al., 2009). From those decisions later challenges may originate. The different phases of the integrated product life cycle are illustrated via the following illustration (Figure 2-3).



Source: Adapted for this research from Döhl (2006)

Figure 2-3 – Integrated product life cycle including the diffusion of innovation

The curves of the illustration describe various areas, in which effort/turnover is made over time. The initial phase of research describes a technology observation phase, in which decisions for the development of technological innovations (encapsulated in a product) are made, before R&D activities follow. Important technological decisions are made before starting R&D. The development is started with a remaining technological uncertainty as risk (dotted line) but also a risk regarding the later success of the product. Activities like risk evaluation need to be considered in marketing technological innovation long before the actual market cycle starts.

In contrast to the effort a company has to make, the market cycle describes the sales numbers of a product range. The actual market cycle of an innovation in many industries can be illustrated by a bell curve representing the sales numbers. The market cycle is the period in time when the diffusion of an innovation takes place by accumulation of individual adoption decisions.

At the end of a product's market cycle, effort is made for its replacement and/or recycling, which can be seen as another cycle (Pfeiffer & Weiss, 1990; Döhl, 2006). The reason for replacement can be the need of a higher technological performance (Pfeiffer & Weiss, 1990). The replacement is mostly performed by a sustaining innovation for the same use case. This can be either a succeeding product model or a new technology with higher performance replacing the out-dated technology.

During the course of diffusion, several challenges may be faced, which might be different depending on the context of the industry and the type of innovation and product. One objective of this investigation is to provide a framework for practitioners for decision-making. Important decisions have to be made in different phases as marked in the following illustration (see the red oval markings in Figure 2-4).

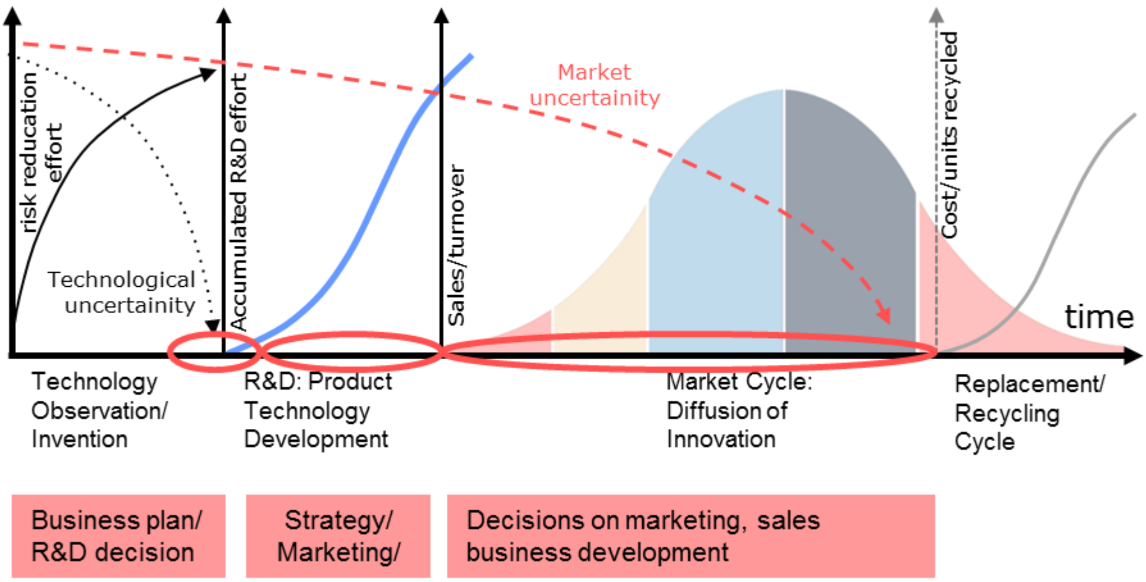


Figure 2-4 – Decision-making situations during the integrated product life cycle

The first phase includes the evaluation of potential challenges when evaluating risks for development decisions regarding both technical uncertainty (dotted line) and adoption/market uncertainty. With the existence of potential problems with the diffusion of innovation, risks can also be illustrated concerning the market (dashed line) along various phases of the integrated product life cycle. Risk management can include those risks and mitigation can be managed. Decisions on marketing measures to overcome potential challenges have to be made, but those measures may change during the course of diffusion.

As the diffusion is mentioned and anticipated within this section, the following section as main body of knowledge gives an overview of existing research and important findings of diffusion of innovation research.

2.2 Main body of knowledge: Diffusion of innovation literature

2.2.1 Origin of diffusion of innovation research

2.2.1.1 Initial disputes between economists and sociologists

Initial research society in the area of diffusion of innovation researched factors and the effects of the diffusion of hybrid corn and seed. Flichy (2007) refers to differences in historical views of economists and sociologists in the 1960s on early diffusion of innovation research. Among several researchers in that area was also Everett M. Rogers (1958), whose understanding of that area was only partially economic.

The aspect of profitability widely exists with adopting an innovation (Flichy, 2007). Therefore, economists favour economic aspects for models of diffusion (Mansfield, 1961; Foray & Le Bas, 1986; Flichy, 2007). The early economist's approach tried to research influencing factors to allow the prediction of the speed of diffusion for a new product (Flichy, 2007). Dixon explains that Zvi Griliches concluded in 1957 that because "…differences in profitability are a strong exploratory variable it is not necessary to appeal to differences in personality, education and social environment" (Dixon, 1980, p. 1451).

The purely economists' view and research on innovation was performed in 1960s, whereas some years before, the diffusion of hybrid corn had been studied (Ryan & Gross, 1943). Their investigation on the diffusion of crop was the subject for sociologists researching the diffusion of this innovation. According to Flichy (2007) both researches, the one of economists and sociologists were performed in parallel in subsequent years and lead to controversial discussions. Griliches (1957) took the position to outline that economic variables are the most dominating ones for the diffusion of innovation. The author's academic opponent and the researcher most known for his book 'Diffusion of Innovation' from 1962 was Everett Rogers. Taking into account that for some farmers the economic aspects of relative advantage may be the most important one for adoption, Rogers even states that "…to argue that economic factors are the sole predictors of rate of adoption is ridiculous" (Rogers, 1983, p. 215). Thus the author took a very clear position directed to the purely economists' view:

"Perhaps if Dr Griliches had ever personally interviewed one of the Midwestern farmers whose adoption of hybrid corn he was trying to understand (instead of just statistically analyzing their aggregated behavior from secondary data sources), he would have understood that farmers are not 100 percent economic men."

(Rogers, 1983, p. 215)

Rogers explains that apart from economic dimensions, there are more motivating drivers existing for the adoption and thus the diffusion of an innovation. An example for such a driver is achieving a certain status within a social group. Unfortunately, those drivers seemed to be more difficult to research for the author:

"… approaches to investigating different motivations for adopting an innovation are needed. Certainly it is not safe to assume, as it often has been in the past, that economic dimensions of relative advantage are the only predictors of rate of adoption … every innovation is judged on economic grounds to a certain degree (by its potential adopters) …"

(Rogers, 1983, p. 217)

Flichy (2007, p. 10) explains the disputes about the influencing factors of the diffusion of hybrid corn among farmers as potential adopters as "…typical conflict between economists and sociologists". The communality relates to the adoption decision, either accepting or declining as response to the innovation (Flichy, 2007).

Similar studies to the ones with corn and seed were performed about drugs by Coleman et al. (1957). According to Flichy (2007), the communalities of the referred studies from the sociologists' view were conclusions that information about the innovation was not necessarily leading to its adoption, but interpersonal contacts.

As a very famous representative for the sociologists' point of view (Flichy, 2007), Everett M. Rogers defined basic elements and influencing aspects for diffusion of innovation. In spite of the controversial views, the research of Rogers has been the starting point for a lot of subsequent studies and is widely seen as an academic foundation for diffusion of innovation research.

2.2.1.2 Diffusion of innovation by Everett M. Rogers

The most known and cited person in literature about theories of the diffusion of innovation is Everett. M. Rogers. His illustrations have been used widely to understand and increase the adoption of products or services for half a century (Rogers, 1962). Rogers (1995) explains diffusion as aggregation of individual adoptions over a period of time as

"… the process by which an innovation is communicated through certain channels over time among the members of a social system"

(Rogers, 1995, p. 5)

According to Rogers, the process of diffusion is influenced by four main aspects. Apart from the innovation itself, the way innovation is communicated, time constraints and a social system with specific attributes and dynamics, into which an innovation is introduced, determine the process. The importance of the combination and integration of these four aspects is illustrated in the following graphic.

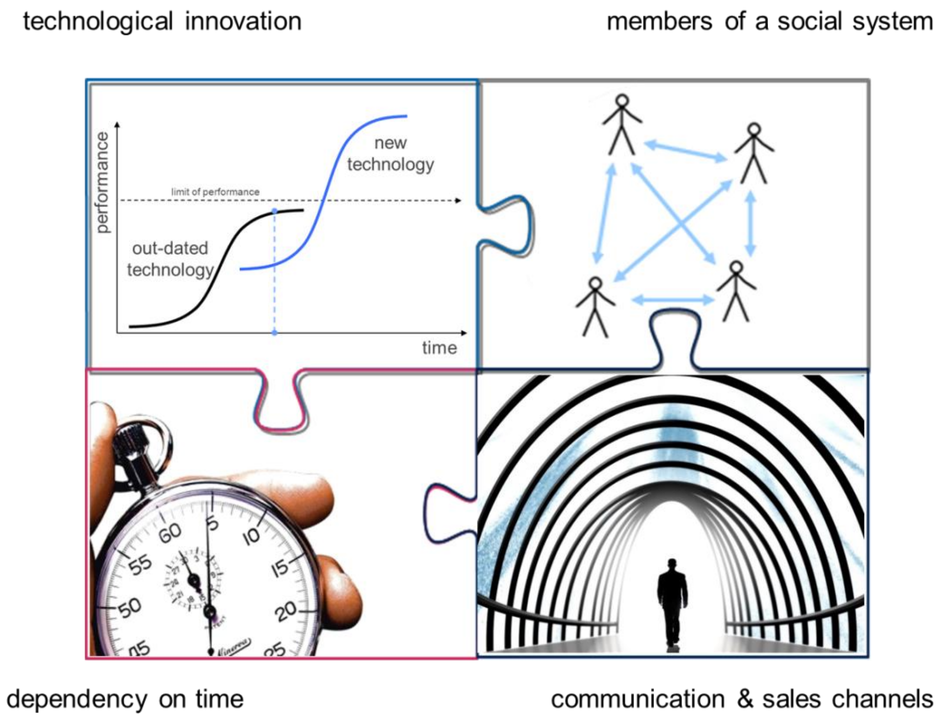
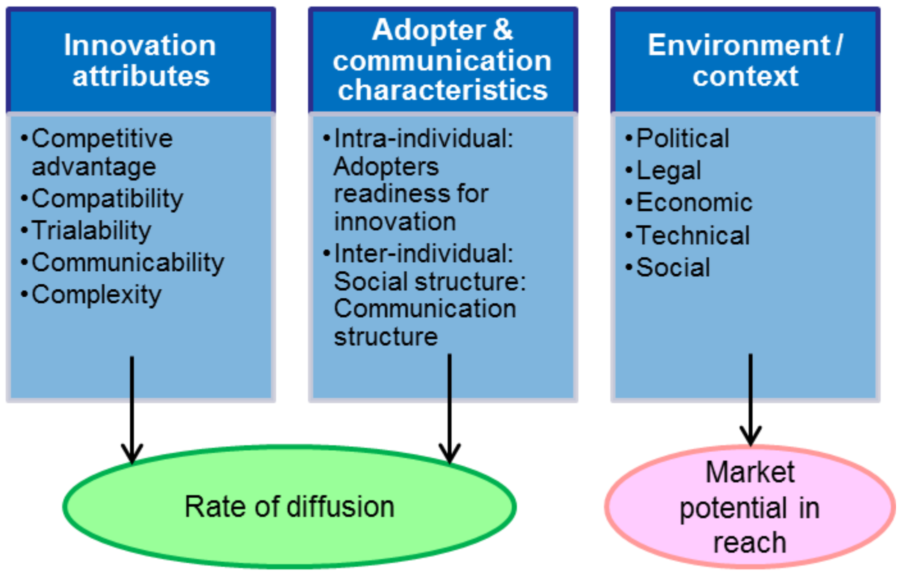


Figure 2-5 – Illustration for Rogers's definition of diffusion of innovation

Applying ideas of the theory of diffusion helps practitioners to understand why a technological innovation is adopted or not. Understanding the diversity of influencing factors for the adoption of an innovation can result in more effective explaining and anticipating barriers or facilitators for diffusion as subject of this research. Sales and marketing practitioners can benefit in the way they approach potential adopters.

The intention with diffusion models is to predict the rate of acceptance for an innovation, the rate of diffusion. According to Rogers (1983) there are different determining factors to take into account with aspects related to the innovation, the person(s) and the environment on an industrial level as the graphic is illustrating.



Source: Developed for this research based on Rogers (1983)

Figure 2-6 – Influencing factors for innovation adoption by Rogers

Rogers (1983) suggests an area of dependency between the diffusion rate and a person-related influence as intra-individual and inter-individual. Additionally, the attributes of an innovation seem to influence the diffusion rate. Furthermore, environmental and context aspects are important for the diffusion regarding the market potential (Rogers, 1983).

The main theories by Rogers (1962) are very often referred to by researches about diffusion of innovation. In an historic study, Rogers and Shoemaker (1971) outline that until 1971 there had already been more than 1,000 studies about this topic. In 1994, Wolfe identifies more than 6,000 articles in a period of only five years (Wolfe, 1994). Eight years later, Nutley et al. (2002) identified almost 15,000 articles including the ones Wolfe identified. The investigations have mostly been about industrial and service innovations (Nutley et al., 2002). Other fields as in cultural evolution (Richerson, 2001) and in public sectors (Nutley & Davies, 2000) do exist as well.

A diversity of literature exists about the process of innovation decision, the technology adoption life cycle based on individual innovativeness, the rate of adoption and perceived attributes. A picture of the most important findings around diffusion of innovation research is drawn within the next section.

2.2.2 Important findings of diffusion of innovation research

2.2.2.1 Adoption as innovation decision progress

Diffusion is a process that takes place over time within a social system as aggregation of individuals on a market level. Each individual undergoes a process of adoption-decision regarding an innovation. Rogers (1983, 1995) distinguishes between five stages as follows:

“The innovation decision process is the process through which an individual (or other decision-making unit) passes from the first knowledge of an innovation, to forming an attitude toward the innovation, to a decision to adopt or reject, to implementation of the new idea, and to confirmation of this decision.”

(Rogers, 1983, p. 166)

Initially a potential adopter has to learn and know about the innovation. After persuasion to the innovation’s merits and forming an attitude, the decision for adoption can be made. After its installation or implementation, the decision gets confirmed and eventually gets reaffirmed or rejected. Rogers's five stages (see also Figure 2-7) for both individuals and decision-making business units (Nutley et al., 2002) are often referred to in diffusion of innovation research:

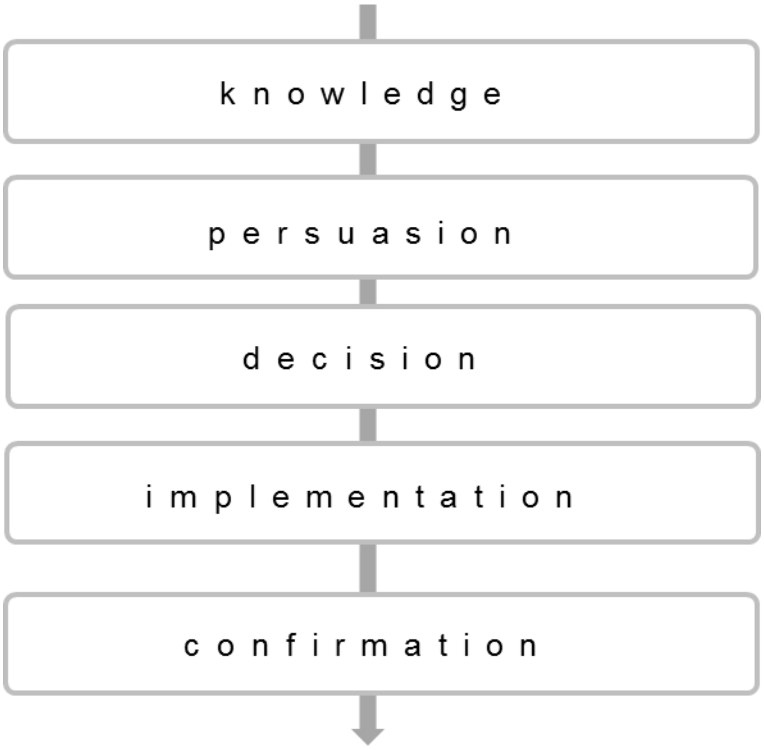
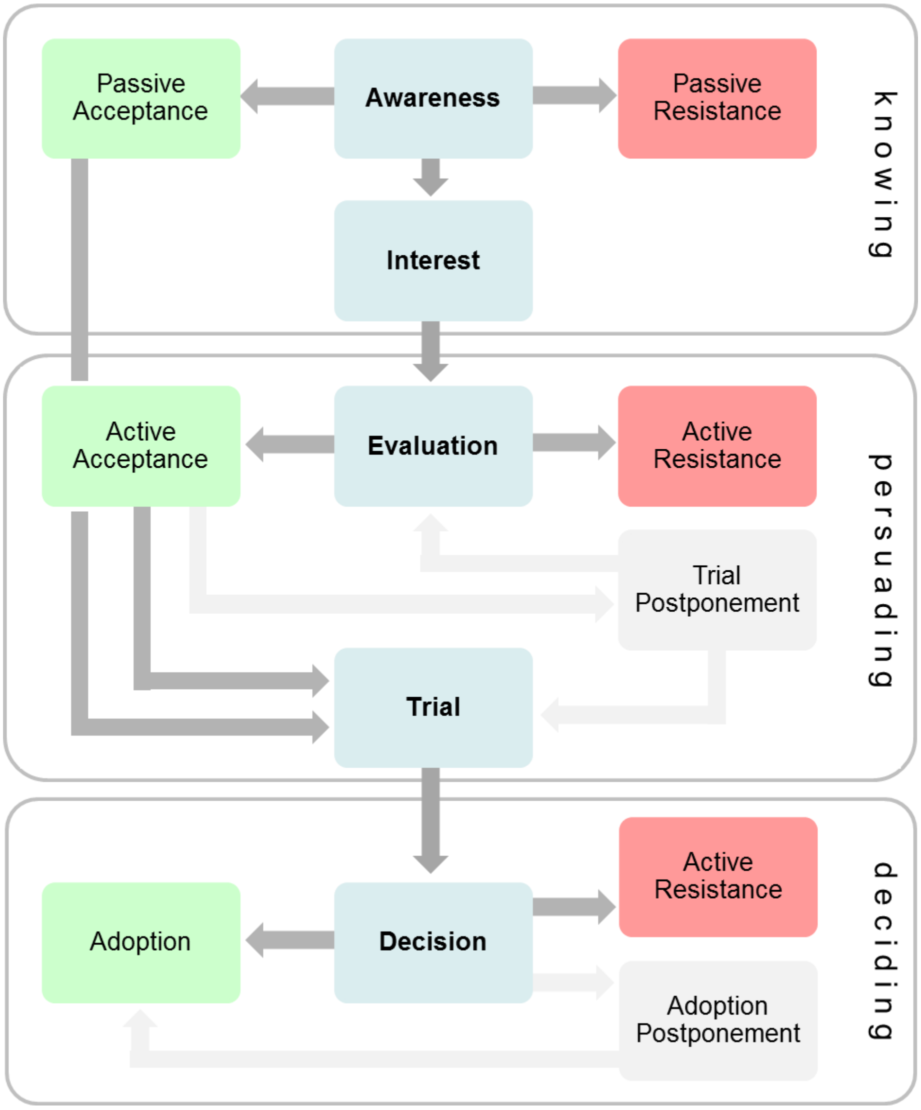


Figure 2-7 – Adoption decision process by Rogers

Other staged models are variations of Rogers's stages. Some (e.g. Rowley, 2011) extend knowledge by additional stages of awareness and interest and persuasion by additional stages of evaluation and trial. In addition to Rogers (1983) explanations of acceptance as positive outcome of the decision stage and resistance as negative outcome, Nabih et al. (1997) describe passive acceptance as positive and passive resistance as negative outcome of an awareness stage of the process.

The following illustration (Figure 2-8) shows the extension of Rogers's stages by the investigations of Nabih et al. (1997) and Hess (2009), which will be used during the course of this research as reference for section 2.3.3. The grey boxes originate from the first three steps of Rogers.



Source: Adaption of Rogers (1983), Nabih et al. (1997) and Hess (2009)

Figure 2-8 – The decision process for adopting an innovation

After the stage of accessing information and gaining awareness, which results in the interest for an innovation, the stage for evaluation follows. Innovation acceptance and innovation resistance are presented as polar results of these initial stages (Rogers, 1983). Hess (2009) explains it as follows:

“At the evaluation stage customers evaluate the acquired information about the innovation and develop an attitude toward the new product. Based on their evaluations, customers then decide at the decision stage whether to adopt or reject the innovation”

(Hess, 2009, pp. 3)

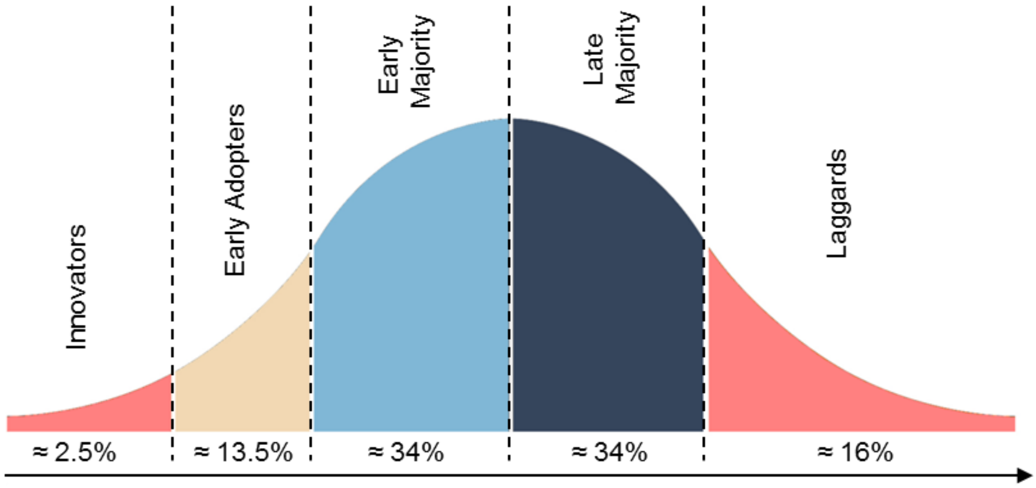
The postponement of the adoption decision is researched by Nabih et al. (1997). The process stages from evaluation to decision are the focus of interest for the research of Hess (2009) about barriers of potential adopters.

It can be criticized that there is lack of incorporating additional aspects, which have to be considered for the process of adoption. The stages focus on individual decision-making whereas other factors, e.g. industrial or governmental constraints, need to be considered as well. All stages seem to be influenced by different factors according to Figure 2-6. Therefore, there is the need for practitioners in marketing, to guide potential adopters through these different steps by appropriate marketing methods (Rowley, 2011). Another perspective is provided by Richardson, who guides potential adopters from a more objective view with basic rules in order to adopt good and reject bad innovations (Richardson, 2001, pp. 356).

As there are various influences and constraints for diffusion of innovation and adoption decisions, diffusion of innovation research provides a variety of findings. The following sections explain the different influences briefly.

2.2.2.2 Adopter categories by individual innovativeness

As an individual's innovativeness as personal readiness for an innovation is different during the course of the diffusion of an innovation, Rogers (1983) distinguishes between different classes of adopters. They are distributed as a bell-curve of individual innovativeness, referred to as technology adoption life cycle. It originates from the s-curve when the number of adopters is illustrated over time (Nutley et al., 2002). Each group represents a certain percentage of potential adopters according to their readiness to innovate:



Source: Developed for this research based on Rogers (1983)

Figure 2-9 – Bell curve of Rogers's adopter categories by individual innovativeness

One extreme of potential adopters are the innovators, because they are ready to take the risk to decide for a technology very early. They follow their beliefs regarding future and can act as good partners in designing product innovations (Moore, 2006).

Early Adopters have the vision to use an emerging technology to go for the company's strategy, driven by a certain 'dream' (Moore, 2006, p.34). This dream is business-oriented with a chance for a high ROI and not technology-focused. As visionaries, they are willing to adopt to get a significant advantage over other potential adopters. Often the beginning lies in a common pilot project (Moore, 1991). According to Robinson (2009), early adopters can provide important feedback for potential improvements of the innovation. They also communicate the new technology within their social environment and are key for word-of-mouth effects (Wangenheim & Bayón, 2007), referred to as contagion.

Together with innovators, early adopters, form a critical mass of adopters of about 16%, to which Finnigan (2009) is referring when explaining a strategy how to convince the other 84%. Very popular literature such as Granovetter (1978), Moore (1991) and

Gladwell (2000) also refer to significant problems after the adoption by this critical mass. The research of Weiber (1992) supports this for network industries.

Early majority is often referred to as a group of pragmatists (Rogers, 2003; Moore, 1991), which are cost-sensitive and try to prevent risk. “They require guaranteed off-the-shelf performance, minimum disruption, minimum commitment of time, minimum learning and either cost neutrality or rapid payback periods” (Robinson, 2009, p. 7). For those kinds of potential adopters, mass media should be used (Moore, 1991; Rogers, 1995; Robinson, 2009).

In contrast to the early majority the late majority are more conservative and sceptical being uncomfortable with new ideas. Laggards are those potential adopters having very weak arguments to refuse adopting the innovation and show long-lasting resistance. Their criticism may influence the behaviour of the late majority (Robinson, 2009).

The readiness for innovation can vary significantly among different potential adopters (Tornatzky & Fleischer, 1990). On many examples (e.g. digital cameras, smart phones, netbooks) we can see ourselves as belonging to one of Rogers’s different groups of adopters. Rogers’s classification of adopters is used widely in diffusion of innovation research, e.g. for adapted sales and marketing strategies (Moore, 1991; Robinson, 2009).

As an adopter can also be a decision-making business unit, its history of success (O’Neill et al., 1998) as well as its strategy, structure, resources and politics (Dean, 1987; Dyer & Page, 1988; Schroeder et al., 2000) may influence the likeliness of a adopting a new technology (Nutley et al., 2002).

Not only adopter categories affect the diffusion. Additionally, the attributes of an innovation, perceived by potential adopters, have to be explained, as the following section shows.

2.2.2.3 Perceived innovation attributes

As different innovations may be adopted at different rates, innovation specific factors as determinant attributes of the adoption can be perceived by potential adopters. Rogers (1983) presents five different attributes, whose characteristics are commented in various investigations (Nutley et al., 2002; Rowley, 2011). The attributes can be illustrated in the order of the following table (Table 2-2).

Innovation attribute	**Description**
Relative advantage	Perceived advantages in comparison to other options (old technology in use or other current alternatives)
Compatibility	The ability of an innovation to match values and experiences of potential adopters
Complexity	The difficulty of understanding and easily integrating an innovation.
Trialability	The possibility of trying the innovation in order to be confident on a limited basis or at limited costs.
Observability	Innovation visibility

Table 2-2 – Innovation attributes according to Rogers (1983)

According to Rogers (1995), modifications and extensions are made to the author's original five attributes, e.g. in allowing re-invention possibilities for an innovation. Moreover, other innovation attributes can be found in literature, such as adaptability and radicalness of an innovation (Wolfe, 1994). Wolfe introduces six attributes that differ from those by Rogers (Nutley et al., 2002). Based on the analysis of facilitating factors of former product launches, Cooper (1985) details aspects regarding the economic advantage, uniqueness, quality and compatibility of a new innovative product in addition to other factors.

Focusing on IT, Davis (1986) presents a model for technology acceptance in which the perceived usefulness (similar to relative advantage) and the perceived ease of use influence the attitude towards using it. Based on this, the research on the use of information systems by Moore and Benbasat (1991) extends Rogers's five factors to eight factors that impact the adoption of IT which are voluntariness, relative advantage, compatibility, image, ease of use, result demonstrability (including observability / communicability), visibility, and trialability.

In contrast to objectively measurable aspects, some explanations outline the importance of individual perception (e.g. Mahler & Stoetzer, 1995). This could also result from a different marketing or different pricing without a needed technological change (Bodenstein, 1971). Those perceptions may also change over time (Kim, 2009). Individual perceptions can also be influenced by intermediaries as the following section shows.

2.2.2.4 Communication channels via mass media and intermediaries

The concept of different communication channels seems to be appropriate for its application depending on alternate points in time and same time for different potential adopters (Rogers, 1995). Besides mass media communication a channel, Rogers's research contains mediating industry experts acting as opinion leaders or change agents to ensure diffusion of innovation. The latter is supported by the research of Katz (1961).

An opinion leader is considered to know more about the innovation than his or her colleagues or peers within the industry. Flichy (2007, p. 12) calls them 'agents of social change'. According to Bodenstein (1971), the main characteristics of opinion leaders are their personalities, their social status and the specific situation. Having adopted the innovation themselves, their role is to convince the majority of remaining potential adopters to adopt and to act as reference. The first 16% of potential adopters can be seen as the pool for opinion leaders (Rogers, 1983; Moore, 1991; Finnigan, 2009). A change agent's credibility (Coleman et al., 1966) and contact frequency (Rogers et al., 1970) do positively influence adoption (Nutley et al., 2002).

In contrast to opinion leaders, change agents are referred to as innovative catalysts who have not adopted the innovation (Rogers, 1983; Moore, 1991; Rogers, 1995). They act as mediators between technical experts and potential adopters (Rogers, 1983, 1995) and are important for interpersonal networks (Nutley et al., 2002). Additionally, interpersonal communication is also possible between potential adopters within a social system (Moore, 1991; Valente, 1995), as the following illustration (Figure 2-10) shows.

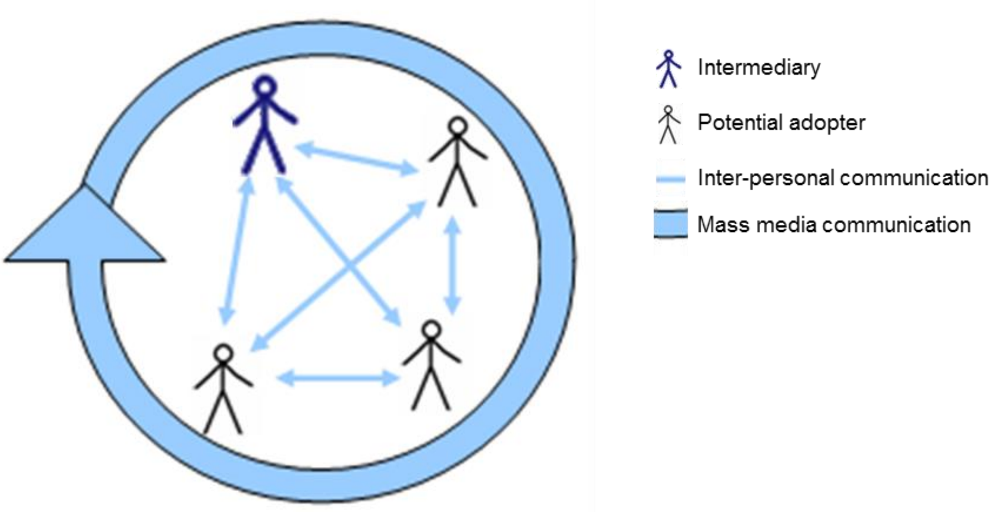


Figure 2-10 – Communication channels for diffusion within a social system

Rogers's concept of distinguished communication channels depends on the different categories of adopters. Early adopters can be convinced by exchanging ideas with intermediaries, as their interpersonal trust is stronger than mass media. However, according to Flichy (2007), the connection between members in a social network is more important than their individual character. The communication channels are different, if the diffusion has reached potential adopters of the early or late majority, in which mass media channels are applied (Moore, 1991; Rogers, 1995).

Mass media channels are effective, if the innovation is less complex (Rogers, 1995). Furthermore, mass media can be important at the "… knowledge stage and interpersonal channels are relatively more important at the persuasion stage" (Rogers, 2003, p. 205) of the decision process. (Nutley et al., 2002)

Moreover, the basic idea of the innovation decision process is social and takes place at each potential adopter along the technology adoption life cycle. The phenomenon of word-of-mouth (WOM) as people talk to people (Rogers, 1995, p. 28) is in accordance with Moore (1991).

The interaction of intermediaries with potential adopters is originally regarded as interpersonal communication within the local social environment (Rogers, 1995). Today, the local focus seems to be changed with the availability of social online networks as investigations of Schnorf (2008) and Harrison-Lord (2010) show.

Besides attributes of an innovation, adopter characteristics and the effectiveness of different communication channels, the environment and context also influence diffusion of innovation.

2.2.2.5 Environment/context dependency

Rogers (1983) illustrates the dependency of diffusion of innovation on environmental and context factors such as political, legal, economic, technically important and social influences.

Rogers's classical model is of centralised nature as related decisions are made centrally. Schon (1967, 1971) questions this top-down approach from experts to users and sees diffusion as decentralised and iterative. Later, Rogers (1995) explains the existence of both, centralised and decentralised systems. In centralised systems, governments often decide on an innovation to be diffused and little adaptation of an innovation is possible for users (Rogers, 1995). Rogers also illustrates that in decentralised systems diffusion takes place horizontally among peers with a high degree of local adaptation (Nutley et al., 2002).

Nutley et al. (2002) summarize further environmental and context factors affecting diffusion with dependencies on uncertainty (e.g. O'Neill et al., 1998) and fashions within a social network (Abrahamson, 1991).

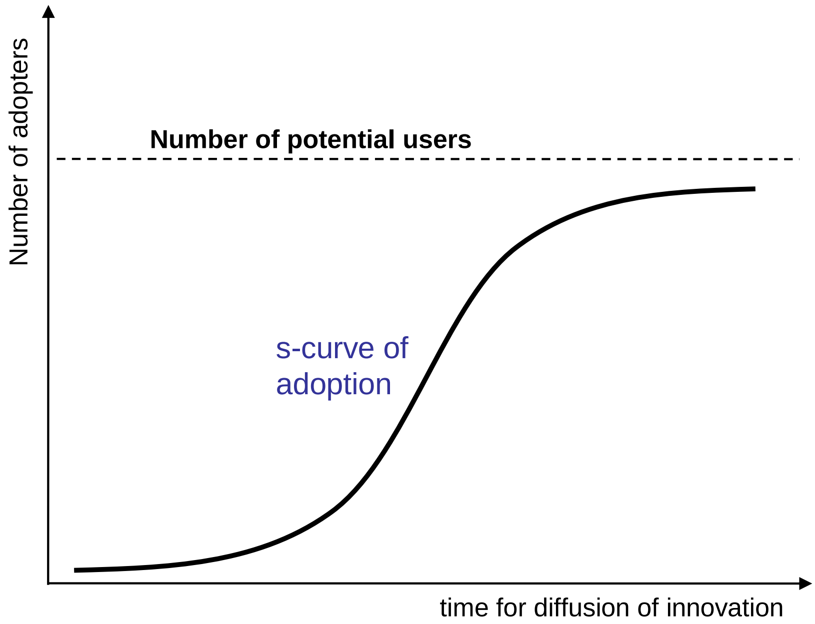
Further importance is also given to the relation of cultural differences and the diffusion of new product innovations (Jain & Maesincee, 1998; Hepp, 1999; Tellis et al., 2003; Asikainen et al., 2004). The recent results of Schumann et al. (2010) underline the importance of cross-cultural differences in WOM and the aggregation of decision-making among adopters, which is also illustrated by McCort and Malhotra (1993). The research findings of Schumann et al. (2010) support the results of Lam, Lee and Mizerski (2009) that the readiness of positive WOM differs across cultures. Practitioners in marketing would be very interested in how to "… counterbalance unwanted effects of negative WOM" (Schumann et al., 2010, p. 74).

The concept of 'Jugaad innovation' (Radjou et al., 2012) describes the environment and context in other economic regions, such as India, as reason for non-adoption of a new complex technology. As a consequence, with the perception of local constraints, other innovation is facilitated and new ideas are promoted for different alternative technologies and easier to implement.

Summing up, besides attributes of an innovation, adopter characteristics and the effectiveness of different communication channels, there is also an influence of the environment and context regarding the adoption rates for the diffusion of innovation.

2.2.2.6 Adoption rate and according mathematical models

The rate of adoption describes the idea that a diffusion of an innovation takes place over time and follows a certain s-shaped pattern (Rogers, 1983). In contrast to the s-curve explained in section 2.1.2, it describes the number of adoptions over time. Initially, there is a period of small growth rate followed by a period of very steep growth. In theory after the period of rapid growth, the rate will find its limit due to a maximum in the number of potential adopters or users as illustrated in the following figure.



Source: Developed for this research based on Rogers (1983)

Figure 2-11 – S-curve representing the adoption rate

In Rogers's diffusion of innovation research, the number of potential adopters as the illustrated asymptote of the s-curve is assumed to be constant for the temporal period of diffusion.

Whereas a lot of publications focus on the process of innovation concerning detailing or simplifying the theory (Cooper & Zmud, 1990; Rowley, 2011) it is questioned whether it is possible to predict the success of an innovation (Van de Ven et al., 1999). For the benefit of anticipating potential adopter behaviour and diffusion development mathematical models for diffusion of innovation are developed based on Rogers's research, e.g. the one of Frank Bass (1969).

Bass (1969) incorporates the rate of adoption concerning a certain installed base of the market based on two coefficients into the model. One describes the influence of innovation, external influence or advertising effect. The other describes the tendency for imitation, internal influence or word-of-mouth effect. The decision for an innovation could only be made once.

As there exist quite some limitations of the original model of Bass, various investigations have been made for its modification. Various models can be differentiated by coefficients as influencing factors, like price for quality (Robinson & Lakhani, 1975), pure price (Mahajan & Peterson, 1978; Kalish & Lilien, 1983), advertising (Parker & Sarvary, 1997; Horsky & Simon, 1983, Kalish, 1985) or instruments of the marketing-mix (Mahajan et al., 1990).

The interrelation of adoption rates and different cultures are researched under a diversity of aspects (Dawar et al., 1996; Yeniyurt and Townsend, 2003; Lam et al., 2009). The dependency of cultural differences is researched regarding the model’s coefficients by Van den Bulte and Stremersch (2004).

For sustaining innovations, at least two generations of technology are involved. Norton and Bass (1987) model the diffusion of a technology generation with two interdependent concurrent diffusion formulas. One technology generation does not initially replace a previous generation but competes with it. The coefficients of their model are modified in further research (Speece & MacLachlan, 1995; Islam & Meade, 1997). The effects of more than two product generations are researched by Mahajan and Muller (1996).

The model modifications and influencing factors as coefficients mentioned show that there is no simple model for diffusion as generalization. The illustrated complexity (e.g. variable coefficients and several technology generations) of accurately modelling a future adoption rate as course of diffusion would require substantiated knowledge among practitioners for its application with the objective of forecasting and introducing a new technology.

The question can be raised, whether such diffusion models are practicable. The following section questions diffusion of innovation research regarding their limitation and implication in practice.

2.2.3 Review of diffusion of innovation research regarding applicability

Focusing on practitioners with concrete needs related to a concrete innovation, the knowledge of diffusion theory should be applicable in an easy way. There are many publications which explain concepts in a very broad way (e.g. Rogers and Shoemaker, 1971; Wolfe, 1994; Rogers, 1995) or provide sophisticated mathematical models (e.g. Norton & Bass, 1987; Mahajan et al., 1995).

However, a practitioner of strategic or product management might be more interested in an easily applicable framework when making decisions under time constraints. The diffusion of innovation research by Rogers (1995) provides basic and widely applied orientation for practitioners. However, Rogers's research has been criticised concerning various aspects.

The assumption for the innovation as 'black box' (Rosenberg, 1982) is that there is no evolution of the innovation (Flichy, 2007, p. 12). An innovative product would remain unchanged and does not progress to improve it (Foray & Le Bas, 1986; Flichy, 2007). With a certain probability for evolution Flichy argues that basic diffusion "…theory has a fundamental shortcoming in so far as it refuses to take into account changes to the technical object" (Flichy, 2007, pp. 12). A modification of diffusion theory is suggested in the form of re-invention (Charters & Pellegrin, 1972; Rice & Rogers, 1980; Rogers, 1995).

Initial models of diffusion of innovation seem to be very static. The number of potential users is assumed to be constant for the diffusion period; it may change, because of technological process and a constant need for change (Flichy, 2007). Also, there is a possibility for decision-making organizations to change in order to implement an innovation (Downs & Mohr, 1976; Mohr, 1987).

Launching a new innovation is a new journey with new circumstances and difficult to predict (Van de Ven et al., 1999). Therefore, practitioners need to make decisions on the development of a new product or on marketing strategies based on a simple framework of influencing success factors.

Many factors can be put into focus for researching and proofing successful launches of innovative technological products. There exist a lot of studies researching facilitators for having successful innovations, of which many refer to Rogers; e.g. regarding innovation attributes (Rogers, 1983). Based on the analysis of facilitating factors of former product launches, Cooper (1985) defines a model, which should support decision-making for or against certain R&D projects. Pfeiffer and Weiss (1990) tailor a list of empirical researches of determinants of successful innovation mostly from the 40s onwards until its publication in the 1990s. However, the aspects considered and the case examples focus on the process of invention and the development phase of innovation and not on factors existing during diffusion of innovation. In addition to that, the empiric research of Milling and Maier lists success factors, e.g. an innovation's uniqueness or factors related to marketing strategy (Milling & Maier, 1996, p. 31).

It mostly is assumed that an innovation contributes to society in a positive way. With an existing 'pro-innovation bias', a well-working system of diffusion widely results in the adoption of an innovation (Nutley et al., 2002, p. 8). Although most investigations support this (Abrahamson, 1991; Hess, 2009), reality shows that a lot of innovations fail, as section 1.1.1 illustrates.

Rogers's work and related modifications illustrate a variety of conditions (innovation and adopter characteristics) and challenges (e.g. unsuccessful communication channels) that can hinder an innovation from its diffusion. Research of facilitating aspects for the diffusion of innovation is widely available. On the contrary, research about non-adoption or unsuccessful diffusion of innovation is limited as Nutley et al. (2002), Selwyn (2003) and MacVaugh and Schiavone (2010) explain. According to Nutley et al. (2002), little research focuses on ineffectiveness, on limiting aspects and non-use of new technology regarding practical approaches (Downs & Mohr, 1976; Van de Ven, 1999).

According to Nutley et al. (2002), there is a tendency for diffusion of innovation research from deterministic and objective definitions of innovation models towards more interpretative orientations regarding social contexts, innovation attributes and knowledge (Van de Ven & Rogers, 1988).

It seems that challenges for the diffusion of innovation have not been researched sufficiently regarding the interpretative applicability of such knowledge by practitioners, e.g. for risk evaluation. Therefore, this study focuses on barriers for diffusion of innovation. Apart from various researches on facilitators for the success of innovations, few investigations (Ram & Sheth, 1989; Moore, 1991; Rogers, 2003; Hess, 2009; MacVaugh & Schiavone, 2010) present models describing barriers. Related literature is reviewed in the following section.

2.3 Research discipline: Barrier frameworks and according barriers

2.3.1 Recent frameworks of barriers for the diffusion of innovation

Besides the wide availability of research about diffusion of innovation, few literatures focus on problematic factors for diffusion (Selwyn, 2003). Pfeiffer and Weiss (1990) present determinants from empirical researches of successful and unsuccessful innovation examples from history but a lot of the referred literature is more than 50 years old. Apart from that, their innovation research is not focusing on diffusion but on invention and R&D.

Reasons for non-adoption and challenges for a slow diffusion are not widely researched. Much of the previous research, for which an overview is given by MacVaugh and Schiavone (2010, pp. 210-213) focus on one or two barrier aspects as findings for diffusion determinants. The focus of others is on one industry only, such as medical devices (Petkova, 2010), construction (Sheffer & Levitt, 2010) or renewable energy (Margolis & Zuboy, 2006). The examples for literature are diverse.

A table with causes of new product failure is presented by Jain (2001) with market/marketing, financial, timing, technical, organizational and environmental failures. Some of these causes are problematic aspects occurring within an organization as a retro perspective. They cannot easily be linked to the diffusion of an innovation. Other publications seem to be incomplete when compared with the different concepts of Rogers (1995). In contrast to that, the research of Kerka et al. (2009) focuses on decision-making for new product development and the appraisal of innovation success potential since some projects prove to flop after their launch. However, their scorecard presents parameters that rather draw the big picture of market potential and financial aspects in order to evaluate innovation ideas. Barriers are explained regarding organizational limits. Although these research works have a different focus, it provides an idea that there is a certain need for frameworks guiding practitioners in decision-making.

Some research works focus on barriers on a macro-level such as of a market or governmental authorities, e.g. as regulatory barriers (Oster & Quigley, 1977), whereas others are on the micro-level of individual adoption decisions (Ram & Sheth, 1989).
As one objective describes the need of focusing on today's barriers, the focus is on recent frameworks and concepts of barriers related to diffusion of innovation based on adoption or non-adoption of new technology. Three concepts were reviewed as follows.
A framework for the micro-level of individual decision-making as economic phenomena is provided by Ram and Sheth (1989), who identify major adoption barriers creating active resistance. Questioning why innovations struggle to be adapted quickly although providing important benefits, the research details Rogers's innovation decision process (Rogers, 1962) and states individual adoption barriers. The research of Hess (2009) refers to more recent literature and extends Ram's and Seth's framework of sources for resistance by cognitive adoption barriers. The framework is presented as 'customer's adoption barriers'.

Another concept describes a phenomen with the existence of barriers at a meso-level, at which the interaction of potential adopters within a community and their characteristics is important. Based on Rogers's research (1962) on adopter categories (see section 2.2.2.2), the concept of the 'chasm' originates from Geoffrey A. Moore (1991) and the author's book about marketing high tech products, mostly being IT. The author describes cracks in the diffusion curve due to different adopter characteristics and explains according reasons, which represent barrier aspects. To overcome them, Moore (1991) suggests various marketing strategies. In further investigations, Moore (1999) provides additional guidelines for moving a product into the lucrative mainstream market. As the author's work is well known among practitioners, especially with its recent edition (Moore, 2006), it is referred to within this research.

Referring to the need of considering phenomena of the micro-, meso- and macro-levels regarding problems with non-adoption or non-use of new technology, MacVaugh and Schiavone (2010) present a multi-dimensional model (see Table A-1), referring to radical products and their non-adoption. With different barrier aspects forming model variables and different domains at the micro-level (individuals), meso-level (community of users) and the market/industry as macro-level it is presented as ‘integrated model of factors limiting innovation adoption’. According to the authors, it should enable practitioners to properly evaluate the probability of success or failing for a new technology ready to diffuse. For the current research it therefore represents a vital potential framework for the study.

In the following sections, the aspects of literature research concerning the different areas and dimensions in which barriers occur are explained according to Moore (1991, 2006), Hess (2009) and MacVaugh and Schiavone (2010).

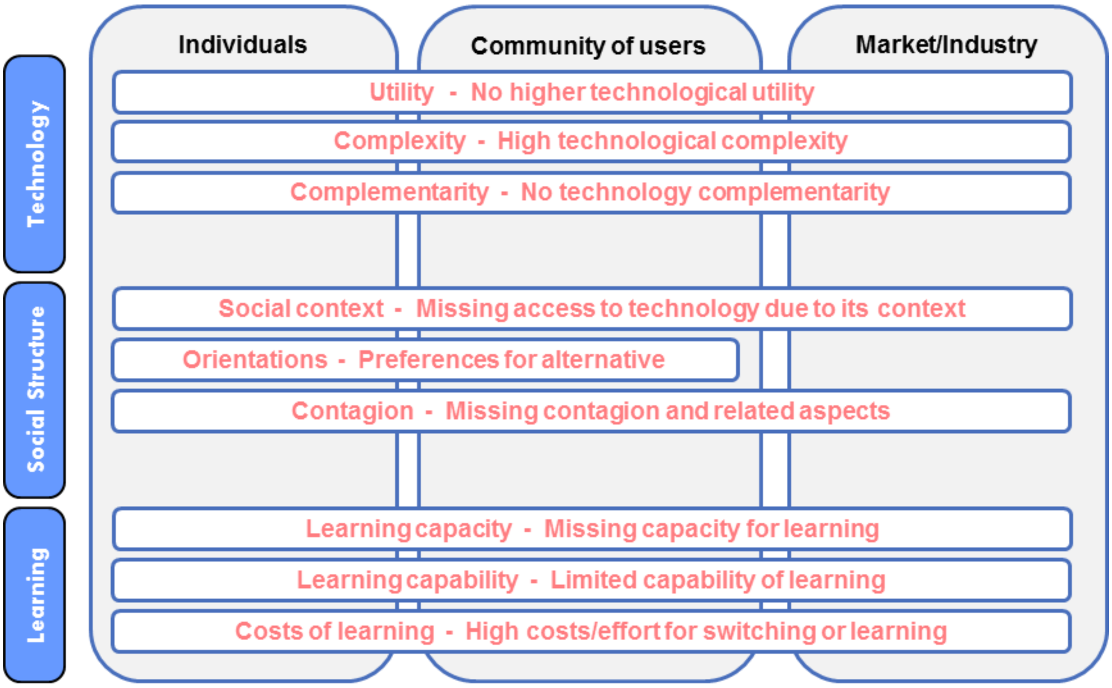
2.3.2 Model of limiting factors to the diffusion of innovation as barriers

2.3.2.1 The model of limiting factors to the diffusion of innovation

The majority of the research undertaken in the 1990s about diffusion of innovation assumes, being in line with Rogers (1962), that because of the motive of utility maximization by the adopter or adopting organization new technology replaces old technology. Assuming adoption for utility-maximizing, MacVaugh and Schiavone (2010) suggest a model of factors limiting the innovation adoption and thus its diffusion, the LF-model. Based on the theory of Rogers (1962), it should help practitioners to be enabled for a proper evaluation of a certain probability of success or flop for a new technology ready to diffuse.

Since its publication the model of MacVaugh and Schiavone has been applied in a diversity of different types of innovation in consumer electronics (Schiavone, 2013, 2014), automotive (Terporten et al., 2012) and IT (Lee et al., 2014) but it is also referred to for the diffusion of International Organization of Standardization (ISO) norms (Llach et al., 2011).

The LF-model is covering different conditions for diffusion of innovation barriers based on technological, social and learning aspects. Each condition contains several levels of influence as for example *utility*, *complexity* and *complementarity* of a technology. The levels of influence represent the variables of the LF-model. Additionally, the variables are researched in different domains as for the players of an individual, a community of users and a whole market or industry, as illustrated in the following (Figure 2-12).



Source: Modified from MacVaugh and Schiavone (2010)

Figure 2-12 – Model of limiting factors to the diffusion of innovation (scheme)

Aspects for technology related conditions are considered with investigations focusing on a technology's *utility*, its *complexity* and its *complementarity*. They are the variables related to the technology itself in the LF-model and represent three of Rogers's innovation attributes. Nevertheless, the other two attributes with triability and observability can be found in the remaining conditions areas.

Regarding the effect of the diversity and constraints of social structures as condition MacVaugh and Schiavone (2010) combine different researches of the last decades focusing on *social context* and on the *orientations* of a social group as LF-model variables. A further LF-model variable contains aspects based on several research approaches how propagating and passing a new technology within a social environment can be facilitating or restricting the diffusion of innovation, described as '*contagion'*.

Accessing information about a technology and learning to apply an innovation are aspects, which have to be considered as well. Researching learning behaviour as third condition, MacVaugh and Schiavone (2010) define variables for *learning capacity*, *learning capability* and effort needed to learn how new technologies would work, the *cost of learning*.

According to MacVaugh and Schiavone, the nine different variables do not have the same complexity in terms of efforts for the identification of subordinate barriers. Moving downwards the LF-model from *utility* to *costs for learning*, the complexity increases.

In the theoretical approach of MacVaugh and Schiavone (2010) several barriers constitute to each level of influence and several sources of information in literature are taken into account. For detailed representation of the LF-model, see Table A-1. Referring to the LF-model, non-adoption may result if one of the introduced players "… is influenced by a condition resulting in negative feedback" (MacVaugh & Schiavone, 2010, p.206). If "…multiple players and condition interactions result in negative feedback, the result is almost certainly non-adoption" (MacVaugh & Schiavone, 2010, p.206).

The following table illustrates the LF-model with the three condition areas and its according barriers constituting to its model variables and the domains of the different players.

New technology fails to **replace older** (or no use of) technology when …			**In the domain of the:**		
			Individual User	Community of Users	Market / Industry
Given the effect of conditions relating to:	Technology	… utility …	… is perceived to be less than the older technology		… fails to exceed the older technology's measurable specifications
		… complexity …	… focuses attention on overall effectiveness not newest feature		… renders really new innovation less frequent
		… complementarity …	… of older technology results in higher total utility		… does no lead to a dominant design
	Social Structure	… context …	… creates material limits to access	… supports social divisions to access	… restricts access on behalf of proprietors / the state
		… orientations …	… towards its use are negative	… are towards the older technology	-
		… contagion …	… is not strong enough to displace existing community norms		… is not dispersed due to poor marketing and/or operations functionality
	Learning	… capacity …	… or cognitive ability limits learning	… to access education is limited	… of resources / guidance is inadequate
		… capability …	… generated by older product use does not assist in new technology use	… of users has not created a community of expertise	… to experience the product is diminished
		… costs …	… related to switching are high		… of learning determined by the product are prohibitive

Source: From MacVaugh and Schiavone (2010) with modified appearance

Table 2-3 – Model of factors limiting innovation adoption and its diffusion (LF-model)

The complexity varies not only among the different levels of influence but also in the different domains. If the context moves from the domain of an individual towards the other domains, in which more people are involved or the level of abstraction is higher, it gets more difficult to assess and know about the barriers as reasons for non-adoption of the new technology.

In the following sections the different model variables are introduced in decreasing order of complexity referring to the according literature. Some sections also mention further literature not being referred to in the LF-model. Each paragraph describes one barrier aspect (one cell) of the LF-model. As each variable represents two or three barrier aspects, the variables are also referred to as barrier variables.

2.3.2.2 Technological utility as barrier variable

Focusing on the effect of conditions relating to technology, its *utility* is one variable defined by MacVaugh and Schiavone (2010) besides its *complexity* and its *complementary* aspects.

Zeithaml (1988) as well as Davis (1989) and Moreau et al. (2001) explain in several approaches that if the utility of a new technology is perceived to be less than the old technology by a social group of users, the technology would fail. With a theoretical approach Zeithaml (1988) focused on the perception of quality and value relating to price. Focusing on IT, Davis (1989) outlines empirically that the successful adoption of a technology can be correlated with the perceived ease of use. Researching IT use, Moore and Benbasat (1991) list relative advantage of a technology among other factors that impact adoption.

Apart from subjective criteria of each potential adopter, there is also an aspect on the macro-level of an industry. If a new technology does not exceed the specifications of the older technology, according to Roure & Keeley (1990) there is no way of driving it to success.

2.3.2.3 Technological complexity as barrier variable

Regarding *complexity*, MacVaugh and Schiavone refer to one barrier aspect for the domains of individuals and the community and mention the following literature. Moreau et al. (2001) focused in their research as well on the aspect that a new technology can also be more complex compared to the preliminary technology. Nevertheless, if the focus is on the overall effectiveness and not the very new and modern functionalities or features this fails as well in the diffusion process concerning Maidique & Zirger (1984). They empirically identified barriers for product innovation explaining special challenges high-tech products have to face during their development and market introduction.

Focusing on the big picture of an industry, the empirical research of Song and Montoya-Weiss (1998) supports the LF-model. It points out that limiting barriers vary depending on the level of innovativeness of a product. For discontinuous innovation, it has to be taken into consideration that markets render those kinds of innovations less frequent according to MacVaugh and Schiavone (2010).

2.3.2.4 Complementarity of technological innovation and technology lock-in

Some industries, especially network industries, can be characterized by a strong dependence on aspects of complementarity, compatibility and standardization (Shy, 2001). It is referred to as ‘technology lock-in’ (Shapiro & Varian, 1999; Shy, 2001). However, it has also to be mentioned that those markets have a big potential for scale-effects. Shy explains that diffusion of innovation is only possible in complementary technological infrastructures. This kind of situation is also referred to as chicken-egg problem (see also section 4.1.3.6).

According to the empirical research of Abernathy and Utterback (1978) about patterns of industrial innovations, a dominant design is a product widely adopted within the industry. Innovations as competing new technologies have difficulties due to the dominant design of the existing technology, even if improvements to products or processes are provided.

In addition to the literature referred to in the LF-model, the aspect of ‘technology lock-in’ (Shy, 2001) led to further literature research. It is of high importance especially in network industries like the one as part of the qualitative research of this thesis. According goods are often called as ‘net effect goods’ (Schoder, 1995), which only bring an added value in a working combination within a network (Schoder, 1995; Weiber, 1992, 1995). Schoder (1995) distinguishes between direct net effect goods with a direct benefit and complementary goods and highlights the need for complementarity. According to Werle (1994) and Schoder (1995), the lack of complementarity in such an industry can result in non-adoption. Garrone et al. (2002) support this by empirical investigations for telecommunications. Therefore, governmental institutions are often involved in the technological way-forward by establishing a standard. Shy (2001) points out that once standardization is achieved, diffusion of innovation is affected positively due to the adoption decisions of big social groups of users. If not, old technology may be longer present in those markets.

2.3.2.5 Social context and access to new technology as barrier variable

Different aspects about technology access are explained by MacVaugh and Schiavone (2010) via the variable of *social context*. Prior studies of the last decades support the domains of the LF-model. The theoretical studies of Krieg (1995) describe one aspect, namely a lack of IT, not allowing individuals to access information in the globalised world. Kling (1999) also mentions access barriers to IT for individual users. In contrast to industrialised countries, some countries do not exist of a big middle class; and Krieg (1995) illustrates that the lack of wealth comes along with unfair and insufficient access to technologies. Not referred to in the LF-model, Van den Bulte and Stremersch (2004) outline a dependency of diffusion rates on income heterogeneity. Selwyn (2003) explains theoretically that personal behaviour, lifestyle and interest strongly determine the use or non-use of IT.

Investigating dynamic social behaviour within communities, Chatman (1996) outlines constraints of information access. The author’s findings describe a problem of bounded information access. Knowledge about the technology is dependant from the insider of the community. Outsiders have limited access to information. Not referred to in the LF-model, Radjou et al. (2012) describe more pragmatic approaches that provide alternatives to new complex technology regarding the community context.

Taylor et al. (2003) describe restricted access in case of endangering an organization's interest or security e.g. by the government. In contrast to that, Hall and Khan (2003) point out that regulatory or governmental interaction have a positive effect on technology adoption. They outline that governmental help can facilitate technology adoption.

2.3.2.6 Orientations towards and preferences for the older technology

MacVaugh and Schiavone (2010) explain that personal orientation towards a technology's use can be negative. Bruland (1995) supports this by a pattern consisting of personal and religious reasons for resistance. Illustrating an alternative perspective, Kingsley and Anderson (1998) describe situations, when internet applications as technology has been adopted but is dropped later on because of a bad experience. MacVaugh and Schiavone (2010) describe this situation as 'discontinuance'. The empirical research of Morris and Venkatesh (2000) discusses the tendency of less technology adoption correlated with increasing age but outlines that the perception of a technology is more important.

The theoretical studies of Brown and Duguid (1991) about adoption and learning process point out, that a community of users influences the orientation towards an old or a new technology. Therefore the relations within a social environment may be facilitating but also limiting. Similar to Rogers (1962), Brown and Duguid (1991) as well as Wenger (1998) investigate the influencing power of a social group of users concerning their learning capability for a new technology and thus the adoption of this innovation. Wenger (1998) and MacVaugh and Schiavone (2010) describe a community of practice as a network with a certain group behaviour, in which decision-making is influenced and relationships are authorized. MacVaugh and Schiavone (2010) summarize that an adoption makes sense to a potential adopter if he/she "…recognises that an innovation may satisfy their needs and be socially accepted and awarded by their community" (MacVaugh and Schiavone, 2010, p.210). It is more likely that technology adoption takes place if opinion-leading experts communicate a new technology as they influence the community effectively (Rogers, 1962).

The presented researches support the individual and community domain of the LF-model. However, MacVaugh and Schiavone (2010) do not consider the existence of negative orientations for a market or industry towards a technology as limiting the diffusion.

2.3.2.7 Missing contagion as spreading word-of-mouth effect and related marketing

MacVaugh and Schiavone use two aspects to describe the variable *contagion*, of which one jointly addresses the impact with individuals and the community as follows. Richins and Bloch (1986) outline with the example of music recording technology that potential adopters with a fanatic interest for the old technology show a stable involvement in preventing a certain new technology. Referring to medical technologies, Coleman et al. (1966) explain that their adoption can be mediated by contagion within a social group. Similar studies examine different drivers of social contagion in the medical environment but personal preferences are as well an adoption barrier (Burt, 1987). MacVaugh and Schiavone (2010) illustrate this on the example of information technology (IT) and its different social use in other cultures. This is supported by Bruland (1995), who explains that older technologies might not be substituted if a new technology does not provide sufficient contagion within a community of sceptics. Bruland also points out that a major subject of diffusion research is the interrelation between the technology use case and its social context (Bruland, 1995).

Focusing on the success of start-ups, the empirical research of Stuart and Abetti (1987) illustrates that the involvement of the founder and their operational experience are key drivers for success. With a theoretical approach, Calantone and Montoya-Weiss (1993) provide a guideline for new product launches and according tasks afterwards. They outline that launching, commercializing and advertising requires a lot of effort, as it is essential to increase the perception among retailers and potential customers. Easingwood and Koustelos (2000) intend to prevent poor marketing of high-technologies and suggest establishing networks and preparing support for learning the technology. They summarize that the consequence of a lack of marketing high-technologies is worse than a technology with a low or lower performance compared to the one of a competitor.

2.3.2.8 Learning capacity to get trained for the new technology as barrier variable

Learning capacity is presented by MacVaugh and Schiavone (2010) as a model variable and has importance in all three domains of the LF-model. According to the empirical research of Cohen and Levinthal (1990), the ability for learning a new innovation of an individual is limited, as their capacity is influenced by already existing knowledge or used innovation.

Miller's (1994) research questions interdependency between the possibility of accessing and participating in training and a gender difference. The empirical findings are a high probability of misbalance of staff who receive access to training. If the access to training possibility is not guaranteed among all potential users within a given community, the diffusion speed of innovation is lower.

Furthermore, the owners of the technology (organisations in R&D or manufacturing) may fail to provide important training within the industry and the market (Hänninen & Sandberg, 2006).

As the ability of using an old technology does not automatically mean, how a new technology could be used, Hänninen and Sandberg (2006) suggest that manufacturers of a new technology should establish an environment that allows learning how to use the new technology or how to appreciate its added value. The lack of such an environment can be the reason for a low diffusion rate.

2.3.2.9 Learning capability in order to use the new technology as barrier variable

Referring to the ability of understanding how to use a technology, Cohen and Levinthal (1990) and Ellen et al. (1991) explain that the perception of the handling and use of a new technology influences their response. MacVaugh and Schiavone (2010) conclude from this that "…older technologies survive when existing learning capabilities do not significantly assist in use of the new technology" (MacVaugh & Schiavone, 2010, p. 206). If an individual person is strongly satisfied by an old or current technology and its use, the resistance of a technology adoption of an alternate innovation is much higher. Literature not mentioned in the LF-model (Moore, 1991; Brucks, 1985; Bower & Christensen, 1995) shows that for discontinuous innovation, a slightly new behaviour is needed for its usage although its basic application remains unchanged. MacVaugh and Schiavone (2010) explain this using the example of voice recognition as digital input.

According to MacVaugh and Schiavone (2010), a further aspect for the variable of *learning capability* is that the needed capability is not created within a community of expertise. Researching discontinuous innovation, Aggarwal et al. (1998) support this by pointing out that learning among the target community is essential for diffusion. Potential adopters without knowledge would not contribute to communicating the learning effects within the social group. A similar research performed by Maryse and Eelko (2008) on e-commerce underlines that the less is known about a new technology, the higher is the probability for non-adoption.

MacVaugh and Schiavone (2010) add that strong and long industry-knowledge prevents a technology from diffusion. Alba and Hutchinson (1987) explain in their research about consumer knowledge constructs that the knowledge of a potential adopter can be dominated either by familiarity or expertise. If such knowledge is present for a popular but old technology and no framework could help to learn how to use a substitution candidate, the likeliness of adoption is very low. The older technology would not be substituted.

2.3.2.10 Costs of learning to handle a new technology

Shapiro and Varian (1999) explain in their theoretical research about economic factors the existence of ‘switching costs’ as one of the main barriers for innovations to diffuse. Apart from procurement, those costs would include all costs arising when switching to another product or technology, such installation, configuration, training and maintenance (MacVaugh & Schiavone, 2010). Because of potentially higher switching costs compared to the potential added value of a new technology, old technologies especially in network industries remain in use for a long time, although their performance is significantly lower. On the contrary, the role of existing knowledge concerning the aspect of quickly learning to apply a new technology was subject to the empirical research of Moreau et al. (2001). The research points out that knowledge of existing product technology can be facilitating, as the advantage and added value of a new technology can be understood more effectively. If knowledge is absent, there might be a negative effect on the adoption due to critical risk allocated with discontinuous innovation in form of a new technology.

In an empirical research, Fornell’s (1992) research concerning factors for customer satisfaction in Sweden support a barrier aspect with learning and associated costs. The author explains that if the costs for learning and switching cannot be afforded the whole industry would rather not decide for such a technology. This and the other aspect related to the cost of learning complete the third level of influencing factors under the condition of learning in the LF-model.

With *costs of learning* as final LF-model variable and after the presentation of the different types of barriers as part of the LF-model in the order of increasing complexity of their assessment, the next section introduces barriers for potential adopters structured by and referring to the innovation decision process. It also shows how the adoption barriers presented by Hess (2009) support those of the LF-model.

2.3.3 Framework of adoption barriers during innovation decision process

2.3.3.1 Overview of the framework of customer's adoption barriers

Researching why innovations struggle to be adapted quickly although they provide essential benefits, Ram and Sheth (1989) identify major barriers creating active resistance. They present a framework of barriers for the evaluation stage of the innovation decision process (see Figure 2-8 from chapter 2.2.2.1), which consists of functional and psychological barriers.

Functional barriers are strongly related to the technological innovation itself and its perception regarding utility and personal learning. Perceived utility and innovation characteristics seem to be very important (Rogers, 1983; Ram, 1987; Haber, 2008). With usage, value and the perceived risk with adopting the innovation, Ram and Sheth (1989) identify three different types. The psychological barriers cover social and cultural aspects, such as existing norms strongly influencing individual orientations towards an innovation.

Focusing on the stage of evaluation, Hess (2009) refers to studies about individual innovation resistance, mostly with disruptive innovation, because consumer attitudes and behaviors with an innovation are confronted with change (Ram, 1987; Eagly & Chaiken, 1995).

Hess (2009) extends this overview of sources for resistance and illustrates instrumental strategies how to overcome these barriers by cognitive adoption barriers. The author extends the framework by cognitive adoption barriers.

The following table (Table 2-4) shows the extended framework with literature describing the barriers and empirical studies for the existence of the barriers during the evaluation stage.

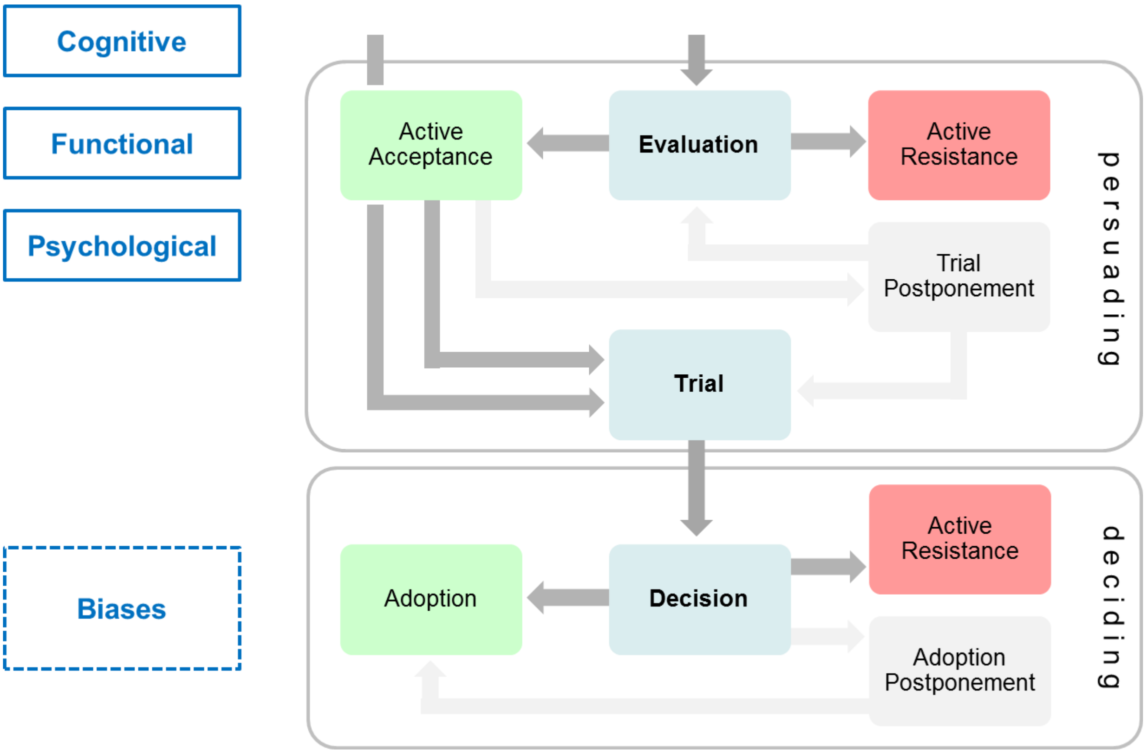
Adoption Barriers (Source for resistance)		Literature describing the barrier	Empirical studies showing existence
Cognitive	Cognitive Barrier	Difficulty of categorization during evaluation: Ozanne et al. (1992) Peracchio and Tybout (1996) Complexity: Rogers (2003)	Moreau et al. (2001) Ozanne et al. (1992) Peracchio and Tybout (1996)
Functional	Usage Barrier	Conflicting with existing usage patterns: Ram and Sheth (1989) Compatibility: Rogers (2003)	Ellen et al. (1991) Mukherjee and Hoyer (2001)
	Value Barrier	Utility compared to old product/technology: Ram and Sheth (1989); Haber (2008) Relative Advantage: Rogers (2003)	De Ruyter et al. (2001)
	Risk Barrier	Associated physical, economic, performance and social risk: Ram and Sheth (1989)	Campbell and Goodstein (2001) De Ruyter et al. (2001)
Psychological	Tradition Barrier	Deviation from existing tradition: Ram and Sheth (1989)	e.g. Antioco & Kleijnen (2007)
	Image Barrier	Negative image associations: Ram and Sheth (1989)	Atkin et al. (2006) Garcia et al. (2007)

Source: Developed for the thesis from Hess (2009, p. 17)

Table 2-4 – List of barriers creating resistance at innovation evaluation stages

According to Hess (2009) innovation resistence is a deadend street in the innovation decision process preventing an innovation from its diffusion. As this research focuses on the barriers themselves, the instruments to overcome those barriers as sources of resistence introduced by Ram and Sheth (1989) and Hess (2009) are not discussed here.

Besides barriers at the evaluation stage of the innovation decision process, Hess (2009) also describes biases and effects for the decision stage. According to Hess, they can result in "…innovation rejection, status quo effect, and default opinions" (Hess, 2009, p. 3). Barriers and bias effects are illustrated by the following graphic (Figure 2-13).



Source: Adaption of Rogers (1983), Nabih, Bloem and Poiesz (1997) and Hess (2009)

Figure 2-13 – Consumer barriers at the evaluation and decision stage

The illustrated active resistence towards a new technology represents negative individual orientation towards its use. According to Bagozzi and Lee (1999) and Haber (2008) the resistance can create a negative WOM, which may turn a whole industry community negatively towards the technology. Such an "…active opposition is the strongest form of resistance" (Hess, 2009, p. 5) compared to passive resistence (Kleijnen et al., 2009) as in Figure 2-8. The active forms of resistence can potentially influence the success of diffusion.

Barriers related to the presented framework for the evaluation stage and additional biases are explained in detail in the following sections. Where applicable, the description links to the LF-model.

2.3.3.2 Usage of an innovation as functional barrier

Existing usage patterns play an important role in the adoption of new innovation as Ram and Sheth (1989) explain using the example of dishwashers and microwaves. Quoting Hoeffler (2003), Hess (2009) explains that new benefits and functionalities need a significant change in the behaviour of consumers as potential adopters.

Hess (2009) refers to Hoeffler (2003) explaining that usage barriers are corresponding with the criterion of compatibility with past experiences supporting Rogers (1962). Technological complementarity results in not having to change any equipment and the capability of learning not having to learn how to use an innovation, also referred to by MacVaugh and Schiavone (2010) via the variables *complementarity* and *learning capacity*. Hess (2009) refers to empirical researches of Mukherjee and Hoyer (2001) and Ellen et al. (1991) to explain individual resistance towards an innovation due to their perception of the difficulty to learn how to use an innovation compared to previous usage patterns. This is supported by Christensen (1997) who outlines that with disruptive innovations, the barrier of different usage patterns gives marketing a significant challenge.

2.3.3.3 An innovation’s added value as functional barrier

Hess (2009) explains that a very important barrier for the diffusion of innovation comes from the individual perception of an innovation’s utility with its attributes and benefits in relation to its price. Referring to Ram and Sheth (1989) Hess calls this barrier a value barrier, whereas it is widely understood as competitive (Porter, 1985) or relative advantage (Rogers, 1995). The value barrier can be described as the perception that the ratio of price and performance is not better than the one of the previous alternative technology (Ram and Sheth, 1989).

Hess (2009) refers additionally to the reference-dependant-model, a model of explaining the possibility of comparing and referencing to an alternative technology used for the same purpose (Tversky & Kahneman, 1991) and mentions the example of e-service (De Ruyter et al., 2001). This barrier is strongly related to the *utility* of a technology, which MacVaugh and Schiavone point out to be a limit for an innovation, if a new technology is "…perceived to be less than the older technology" (MacVaugh & Schiavone, 2010, p. 208).

2.3.3.4 Different risks resulting in resistance as functional barriers

A barrier to an innovation can also be a certain risk or uncertainty (Rogers, 2003). According to Ram and Sheth (1989), with physical risk, economic risk, functional risk and social risk, several types of risks can be understood as barriers leading to resistance to an innovation. Potential adopters need to see the risk manageable or minimized.

"All innovations, to some extent, represent uncertainty and pose potential side effects that cannot be anticipated. Customers, aware of the risks, try to postpone adopting an innovation until they can learn about it."

(Ram & Sheth, 1989, p. 8)

Ram and Sheth (1989) outline that an adoption decision may be postponed because of existing risks until there is a capability of learning the innovation. Potential adopters may also fear a social risk. However, Hess (2009) points out that the main types of risk for the purchasing of an innovation are performance, financial and physical risks (Kaplan et al., 1974). Concerning an economic risk, Vowe and Will (2004) refer to gross or net benefit, which if absent or too low can result in non-adoption.

Uncertainty may exist with doubts that an innovation would come with high functionality or performance expected due to missing functional tests. An economic risk is perceived especially with big investments of industrial goods, as there is an uncertainty remaining on installation costs and costs for learning. Another aspect on financial risk can be referred to with electronic goods and the fear of future price reduction. Related to financial risk, a technology with the potential of endangering persons or property is evaluated as being a risky investment due to physical risk. (Ram & Sheth, 1989)

The research of Sheth (1981) identifies positive correlation between the level of disruptiveness of an innovation and the perceived risk for applying and learning a new technology.

According to Hess (2009), associated risks are the reason why the evaluation of an innovation results in a reduced intention for its adoption. This is supported empirically (Campbell & Goodstein, 2001; De Ruyter et al., 2001). Campbell and Goodstein (2001) explain that perceived risks can lead to preferences for congruent products. Some potential adopters would even overestimate potential failures, which might occur (Heiman & Muller, 1996). Risk management evaluates risks, its probability and its impact on cost and schedule (Mulcahy, 2009). A certain risk represents calculative costs and usually accruals have to be foreseen. The evaluation of a risk is also of monetary nature.

2.3.3.5 Tradition and image as psychological barriers

There can also be psychological resistance, e.g. related to cultural values. Innovation can require significant cultural change related to existing traditional values. Individual behaviour might not be in line with social norms or social and family values (Ram & Sheth, 1989). Ram and Sheth (1989) provide a lot of examples and explain that as long as attitudes are not changing, this kind of barrier remains. Hess supports this, referring to the empirical study of Antioco and Kleijnen (2007).

Apart from tradition, Ram and Sheth (1989) mention that innovation comes along with a certain identity due to its product class, industry or country of origin they are associated with. If the associations are negative although it might only be a stereotype, there exists a barrier of adoption. They illustrate an image barrier describing India as a country where big numbers of industrial machine tools are manufactured, but unfortunately it is associated with a negative image. Hess (2009) gives the example of screw cups in the wine industry with a negative image (Atkin et al., 2006; Garcia et al., 2007).

2.3.3.6 Cognitive adoption barriers

Depending on different levels of discontinuity and disruptiveness, according to Hess (2009) cognitive aspects play a role in adopting an innovation. Hess's research is supported by various investigations (e.g. Peracchio & Tybout, 1996; Mukerherjee & Hoyer, 2001) on needed cognitive efforts for a new product innovation. Evaluating innovation, individuals need to position it within existing patterns and categories of knowledge (Ozanne et al., 1992; Bloch, 1995). This is supported by other research (Moreau et al., 2001).

The task to categorize an innovation into the referred existing patterns is quite challenging (Hess, 2009), especially if the innovation is very complex (Rogers, 2003; Gatignon & Robertson, 1991), discontinuous (Hirschman, 1982) or even disruptive (Cox & Locander, 1987).

2.3.3.7 Innovation and status quo biases and resistance effects

According to Hess (2009) adoption decisions are made based on the perceived value with the constraint of information limits for its performance (Jensen, 1982). Furthermore, Hess explains that decision-making occurs at potential adopters with limited rationality, based on the behavioural decision theory by Edwards (1954). This results in innovation bias, supported by Gourville (2005). Gourville explains the tendency to overvalue currently used technology even if new technology is superior. Hess (2009) refers to the 'endowment effect' and 'status quo bias' referring to according literature (Samuelson & Zeckhauser, 1988; Kahneman et al., 1991). Therefore, a new technological innovation sometimes has to face a very strong positive opinion about the technology used so far.

Innovations are rejected by potential adopters and referring to the reference-dependant-model (Tversky & Kahneman, 1991), Hess explains that:

"… the reference point in the adoption decision is the existing product and losses customers will incur by switching to the new product will weigh more than the gains expected from the innovation. "

(Hess, 2009, p. 20)

Referring to Gourville (2005) and to the regret theory of Loomes and Sugden (1987), Hess additionally explains that potential adopters might regret to give up their old technology currently in use and therefore they would not perceive a higher utility with the new technological innovation.

Very closely related to the innovation bias, status quo bias represents the limited rationality of potential adopters (Gourville, 2005; Hess, 2009). Initial empiric research to confirm that individuals tend to rather prefer the status quo is performed by Samuelson and Zeckhauser (1988). Hess (2009) refers to the introduced reference point dependency (Tversky & Kahneman, 1991) and regret theory (Loomes & Sudgen, 1987). Hartman et al. (1991) show empirically that the majority of customers of electric utility would rather not change their contractual situation and would remain in a status quo. When potential adopters are satisfied with what they have so far, the status quo would be preferred (Luce, 1998; Inman & Zeelenberg, 2002). Focusing on innovation, Hess (2009) refers to Ellen et al. (1991), who illustrate that satisfied users of an established technological approach would not replace the existing processes by highly automatized ones. Potential adopters can stick to their status quo to avoid potential regret and negative emotions.

In addition to the barriers occurring at the evaluation stage, the biases occur at the decision stage of the process of innovation decision of individual adopters (Hess, 2009). Furthermore, the awareness and interest stages (see Figure 2-8) are addressed by Moore (1991), assuming that potential adopters talk and refer to each other. Related barrier aspects of Moore's concept are illustrated in the following section.

2.3.4 Chasm concept and related barriers for diffusion of innovation

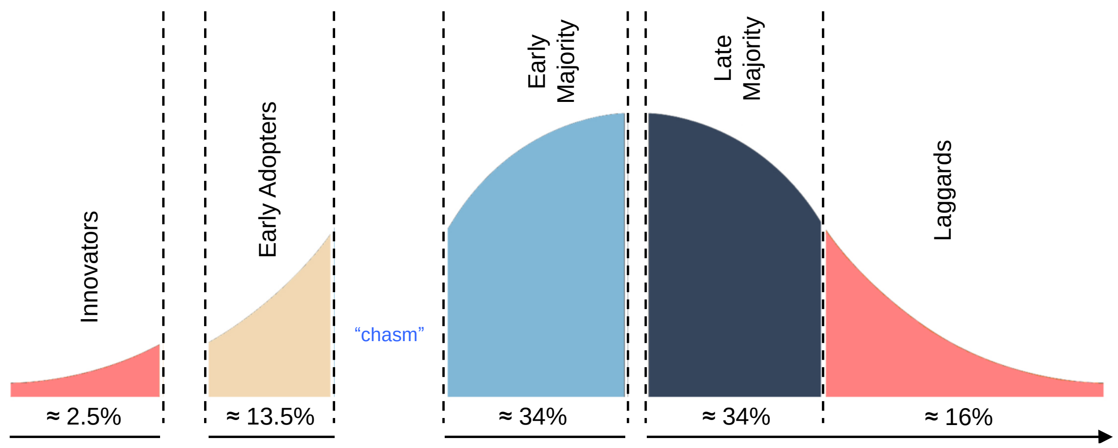
2.3.4.1 Overview of the bell curve cracks of the technology life cycle

The term ‘chasm’ relates to the research by Moore (1991) about marketing high tech products. While Hess (2009) and Ram and Sheth (1989) focus on individual adoption decision, Moore’s focus is on the communication between individuals within a community. Moore illustrates this by defining a market as:

“… for the purposes of high tech, as
- a set of actual and potential customers
- for a given set of products or services
- who have a common set of needs or wants, and
- who reference each other when making a buying decision”.

(Moore, 2006, p. 28)

Referring to disruptive or discontinuous types of innovation in high-tech markets, Moore explains that the tendency of potential adopters to reference each other when making a buying decision "… is absolutely key to successful high-tech marketing" (Moore, 2006). Adapting the diffusion of innovation research about the technology adoption life cycle (Rogers, 1983), Moore points out that there exist gaps between psychographic groups as the following graphic shows.



Source: Adapted from Hoff (2009)

Figure 2-14 – Revised technology adoption life cycle with cracks in its curve

The cracks illustrate that there is a "…difficulty any group will have in accepting a new product if it is presented in the same way as it was to the group to its immediate left" (Moore, 2006, p. 16). Moore describes the consequence as follows:

"Each of these gaps represents an opportunity for marketing to lose momentum, to miss the transition to the next segment, thereby never to gain the promised land of profit-margin leadership in the middle of the bell curve"

(Moore, 2006, p. 16)

The biggest crack in the bell curve, the chasm, appears between distinct market places; "…the first, an early market dominated by early adopters and insiders who are quick to appreciate the nature and benefits of the new development, and the second a mainstream market" (McKenna in Moore, 2006, p. xiv).

The understanding of different types of attitudes of potential adopters and their decision-making, which can be influenced by other adopters, determines the success of an innovation in relation to its adoption rate (Moore, 1991). Norman (1998) outlines aspects for the diffusion of innovation relating to the life cycle of technology, which support Moore (1991). Gladwell (2000) supports this as well for other markets than high-tech. Rogers disagrees in the fifth edition of 'Diffusion of Innovation' (2003), proposing that the different groups of potential adopters form one population (2003, p. 282). Robinson (2009) mediates, outlining that early adopters and early majority have essentially different mind-sets, and explains chasm as warning for marketing and sales. During cracks in the diffusion curve like the chasm, several problems occur (Moore, 1991). Referring to the example of artificial intelligence in information technology, Moore (1991) makes clear that its early majority was never reached, and mentions that

"… there were too many obstacles to its adoption: lack of support for mainstream hardware, inability to integrate it easily into existing systems, no established design methodology, and a lack of people trained in how to implement it … lack of a sustained marketing effort"

(Moore, 2006, p. 22)

Those barriers have to be considered, which are related to the basic idea of Rogers (1962) and Moore (1991) that potential adopters do reference each other. A bad word-of-mouth effect can prevent an innovation to become popular (Gladwell, 2000). To overcome and "…to lower the barriers to adoption (Moore, 2006, p. 22)", Moore suggests various marketing strategies. Those barriers, Moore (1991) describes, are referred to in the following sections.

2.3.4.2 Barriers related to the crack between innovators and early adopters

Moore points out that the first crack in the bell curve is between innovators and early adopters, as it occurs "… when a hot technology product cannot be readily translated into a major benefit (…). The enthusiast loves it for its architecture, but nobody else can even figure out how to start using it" (Moore, 2006, p. 17).

The explanation for this crack is closely linked to the barrier of perceived utility compared to a previous technology (MacVaugh & Schiavone, 2010). Moore gives the example of neural networking software (Moore, 2006, p. 17). To fight that barrier, Moore suggests clearly showing and explaining the new value for the understanding of a non-technologist. Potential adopters need to get explained that the new technology enables a strategic move forward in comparison to the old technology (Moore, 1991).

2.3.4.3 Barriers related to the crack between early adopters and early majority

According to Moore (1991), the most important crack in the bell curve lies between the early adopters and the early majority due to different expectations and perceptions. Early adopters are motivated to change their business dramatically being the first to apply something radically new, whereas the early majority wants to improve their existing way of business. Adopters from the early majority "… want evolution not revolution" (Moore, 2006, p. 20) and therefore it is important to have the possibility of measurable specifications compared to the old technology.

For the early majority "… good references are critical to their buying decisions" (Moore, 2006, p. 20). Moore explains this as a catch-22 situation because other adopters of the early majority do not decide to adopt "… without first having consulted several suitable references" (Moore, 2006, p. 20). This situation is about a serious problem after some initial success of an innovation among innovators and early adopters.

Not distinguishing between the different groups of the technology adoption life cycle, MacVaugh and Schiavone (2010) describe this barrier in the area of the social structure, when contagion is not strong enough to displace existing community norms.

Good marketing may lead to a wide contagion. But especially for discontinuous innovations, a "…inability of the marketing effort (…) to lower this barrier to the early majority" (Moore, 2006, p. 21) can be seen as barrier, which supports the investigation of MacVaugh and Schiavone (2010).

2.3.4.4 Barriers related to the crack between early majority and late majority

Another crack in the bell curve according to Moore (1991) happens to be between the group of early and late majority due to different levels of technological competence. "Simply put, the early majority is willing and able to become technologically competent, where necessary; the late majority, much less so" (Moore, 2006, p. 18).

For the late majority some technological features of their products are used little and cannot easily be remembered (Moore, 1991). As a result "… the end user cannot capture the benefit" (Moore, 2006, p. 18). MacVaugh and Schiavone (2010) refer to this as limits in the *learning capacity* or ability and *learning capability* besides a barrier variable regarding *utility*. The late majority tends to have a different capacity of learning in comparison to the early majority, as Moore (1991) explains.

Moore claims that these barriers exist because of a lack of marketing, as they fail to communicate the user experiences with the new technology (Moore, 2006, p. 19). However, with poor marketing, a needed contagion in the industry might not be achieved, considered as *contagion* variable by MacVaugh and Schiavone (2010).

With the introduced barriers related to the bell curve cracks of the technology adoption life cycle (Moore, 1991); a third approach of structuring the existence of barriers for innovation is introduced. The following section gives an overview of the three different approaches. Following the research objectives, it questions which approach would be most suitable for a framework and its usage by practitioners.

2.4 Research discipline: Critical review of barrier frameworks

2.4.1 Summary of different approaches for structuring diffusion barriers

Nutley et al. (2002) suggest criteria for a comparison of the different concepts and models in the research of diffusion of innovation regarding their link to its utilization for research. The following table gives an overview of the different models (being part of this thesis) applying the suggested criteria.

	Model of limiting factors to the diffusion of innovation (MacVaugh & Schiavone, 2010)	**Chasm concept for diffusion of innovation (Moore, 1991, 2006)**	**Customers' adoption barriers (Hess, 2009)**
Type of knowledge	Literature research with theoretical data	Book with mainly theoretical information	Literature research with theoretical data and extension by empirical data
Type of utilization:	Model directed to practitioners based on literature referring to a diversity of industries since the 1960ies	Concept of a specific diffusion problem and suggestions to solve it with a focus on IT industry of the late 1990s referring to both, industrial and consumer goods	List of barriers and instruments to overcome them which can help for developing suitable marketing campaigns
Used model:	LF-model organized in different abstraction levels (domains) and different levels of influence (technology, social structure and learning as major areas)	Chasm as gap between innovators and majority of adopters based on the technology adoption cycle as part of Rogers's theory of the diffusion of innovation	Listing of barriers for diffusion of innovation at the evaluation stage and decision stage of the adoption process as part of Rogers's theory of the diffusion of innovation
Perspective:	Objective view of micro, meso and macro levels	Mostly meso-level as transition from macro to micro	Mainly micro-level
Key findings:	Summary of barriers on micro and macro	Chasm as gap between innovators and majority of adopters	Barriers on the micro level of consumers and suggestions to overcome those

Table 2-5 – Comparison of approaches for structuring diffusion barriers

In contrast to the research of the LF-model, the authors of the chasm concept and adoption barrier investigation illustrate possibilities to overcome existing barriers. Table 2-5 demonstrates that the LF-model takes different perspectives although it is of theoretical nature. It gives an overview of diffusion barriers, directed to practitioners.

Researching valid models for technological innovations and according concepts, it is not only important to research the applicability in various industries but also to cross-link to other models. Therefore, a comparison of ideas and aspects related to barriers of Moore (1991) and customer's adoption barriers of Hess (2009) and the LF-model by MacVaugh and Schiavone (2010) is performed. With the introduction of the different models, some cross-links and interrelations are presented in the following sections.

As the LF-model provides different views on the micro, meso and macro level, mapping is performed against an empty LF-model template. For mapping another approach to the LF-model, the barriers clearly identified are described and entered into the table and the according cell is coloured white. If a cell out of the LF-model cannot clearly be mapped to, the cell remained grey and is marked with an 'x'. If the whole domain is not considered, the cells are crossed out. In case a barrier seems to occur in more than one domain the cells are merged. Supporting secondary literature is as well listed similar to the approach of MacVaugh and Schiavone (2010). In case no secondary literature is available, a suitable citation is entered in the according cell.

The next section compares innovation adoption barriers during the innovation decision process as part of the research of Ram and Sheth (1989) and Hess (2009) with the LF-model. Thereafter, subsequently diffusion barriers at the cracks of the technology adoption life cycle as part of Moore's chasm concept are compared with the LF-model.

2.4.2 Decision and evaluation of a suitable framework

2.4.2.1 Mapping of customers´ adoption barriers during innovation decision

Barriers as subjects for the research of Ram and Sheth (1989) and Hess (2009), which occur during the innovation decision process, are researched focusing on individual decision-making. This mainly supports the first domain of individuals in the LF-model (MacVaugh & Schiavone, 2010). Other barriers support both, the domain of the individual user and the community of users. The following table gives an idea, how the barriers of Hess (2009) contribute to the LF-model.

<table>
<tr><th colspan="3" rowspan="2"></th><th colspan="3">Domains</th></tr>
<tr><th>Individual User</th><th>Community of Users</th><th>Market / Industry</th></tr>
<tr><td rowspan="10">Conditions</td><td rowspan="3">Technology</td><td>… utility …</td><td colspan="2">“Value barrier” (Ram & Sheth, 1989; Hess, 2009) supported by “Relative Advantage” (Rogers, 2003)
“(economic , physical & functional) risk barrier” (Ram & Sheth, 1989; Hess, 2009)</td><td></td></tr>
<tr><td>… complexity …</td><td colspan="2">“Cognitive barrier” (Hess, 2009) supported by “Complexity” (Rogers, 2003)</td><td></td></tr>
<tr><td>… complementarity …</td><td colspan="2">“Usage barrier” (Ram & Sheth, 1989; Hess, 2009) supported by “Compatibility” (Rogers, 2003)</td><td></td></tr>
<tr><td rowspan="3">Social Structure</td><td>… context …</td><td>x</td><td>X</td><td></td></tr>
<tr><td>… orientations …</td><td>“Cognitive barrier” (Hess, 2009)
“Image barrier” (Ram & Sheth, 1989; Hess, 2009)
“(social) risk barrier” (Ram & Sheth, 1989)
Biases and resistance effects (Hess, 2009) supported by:
- “Reference-dependant-model”(Tversky & Kahneman, 1991),
-“endowment effect“ (Kahneman et al., 1991; Hess, 2009),
-“status quo bias“ (Inman & Zeelenbert, 2002, Luce, 1998; Harmann et al., 1991; Garville, 2005; Samuelson & Zeckhauser, 1988; Hess, 2009)
- “Regret Theory” (Loomes & Sudgen, 1987; Hess, 2009)</td><td>“Tradition barrier” (Ram & Sheth, 1989; Hess, 2009)
Biases and resistance effects (Hess, 2009) supported by:
- “Reference-dependant-model”(Tversky & Kahneman, 1991),
-“status quo bias“ (Inman & Zeelenbert, 2002, Luce, 1998; Harmann et al., 1991; Garville, 2005; Samuelson & Zeckhauser, 1988; Hess, 2009)</td><td></td></tr>
<tr><td>… contagion …</td><td colspan="2">Active resistance as consequence (Ram & Sheth, 1989; Hess, 2009)</td><td></td></tr>
<tr><td rowspan="3">Learning</td><td>… capacity …</td><td>“Cognitive barrier” (Hess, 2009)</td><td></td><td></td></tr>
<tr><td>… capability …</td><td>“Usage barrier” (Ram & Sheth, 1989; Hess, 2009) supported by “Compatibility” (Rogers, 2003)</td><td></td><td></td></tr>
<tr><td>… costs …</td><td colspan="2">“(economic) risk barrier” (Ram & Sheth, 1989; Hess, 2009)</td><td></td></tr>
</table>

Table 2-6 – Customer’s adoption barriers of Hess (2009) mapped to the LF-model

Introduced as ‘value barrier’ (Ram & Sheth, 1989; Hess, 2009), the perceived utility of an innovation in comparison to the old technology also known as relative advantage (Rogers, 2003; Porter, 1985), is reflected in the LF-model by the variable of *utility*.

Referred to as ‘usage barrier’ (Ram & Sheth, 1989; Hess, 2009), the usage pattern of an innovation plays an important role for its diffusion. They refer as well to compatibility (Rogers, 2003) which addresses both, the compatibility of usage behaviour and the usage of complementary devices. Both are reflected in the LF-model by the variables of technological *compatibility* and *learning capability*.

Hess (2009) extends the model of Ram and Sheth (1989) by cognitive adoption barriers. The identified barrier should be seen in the individual domain of the LF-model only, as the cognitive setting influences every single evaluation of an innovation. In the LF-model, there is the difficulty of identifying a clear categorization. The complexity of a new technology, personal orientations and the cognitive learning ability as the learning capacity can be taken into account. Its existence can additionally be seen within the community of users regarding technological complexity, as individuals evaluate a new technology based on existing patterns within the community of users.

Psychological barriers (Ram & Sheth, 1989; Hess, 2009) from sociology and psychology areas of research relate to image and tradition. They can be seen as represented by the variable of *orientations* in the domain of individuals and the community of users. The image barrier rather influences an individual when evaluating an innovation, whereas the tradition barrier exists within a community of users.

Perceived risks as barriers (Ram & Sheth, 1989; Hess, 2009) can be accounted for variables in different conditions of the LF-model. Perceived risks for performance and costs concerning a cost-utility ratio can be applied as part of technological *utility* as well as physical damage risk. However, the risk of costs can be perceived with the *costs of learning* as variable. Richerson (2001) explains this risk to potential adopters by warning them that those “… who would invent, or even adopt most proffered innovations, have to be prepared to pay some learning costs“ (Richardson, 2001, pp. 356). A social risk (Ram & Sheth, 1989) would rather be covered by individual orientation towards a technology as part of the LF-model variable *orientations*.

In addition, Hess (2009) explains theories on the decision stage of Rogers’s (2003) innnovation decision process. Explaining theories about innovation and status quo biases and resistence effects, Hess gives an idea of the barrier of individual orientation, which might be negative towards an innovation. Apart from personal orientation, the ‘endowment effect’ (Kahneman et al., 1991) referred to by Hess (2009) also supports the LF-model explanation for non-adoption, in which the utility of the old technology is valued higher. To Hess (2009) one of the most suitable theoretical concepts to explain a personal orientation towards an old technology is the ‘status quo bias’.

Since the publications of Ram and Sheth (1989) and Hess (2009) focus on customers’ adoption barriers, the described barriers mainly support the domain of individuals in the LF-model. With Table 2-6, an illustration is provided with the main focus of barriers on consumer decisions by their integration into the LF-model of the research of MacVaugh and Schiavone (2010). A similar comparison and illustration is performed for Moore’s (1991) chasm concept, as the following section explains.

2.4.2.2 Mapping of diffusion barriers at the cracks of the chasm concept

This section focuses on various crosslinks between cracks in the bell curve of the technology adoption life cycle (Moore, 1991) and the LF-model (MacVaugh & Schiavone, 2010). Of the three introduced cracks in the bell curve, Moore (1991) clearly states the one between the early adopters and the early majority (the chasm) as the most serious problem of marketing technological innovations.

Several explanations of Moore (2006) support the findings of MacVaugh and Schiavone regarding its model variables mainly in the domains of individuals and of the community of users. The following table (Table 2-7) gives an idea, how the explanations of barriers by Moore (2006) contribute to the LF-model.

<table>
<tr><th colspan="3" rowspan="2"></th><th colspan="3">Domains</th></tr>
<tr><th>Individual User</th><th>Community of Users</th><th>Market / Industry</th></tr>
<tr><td rowspan="9">Conditions</td><td rowspan="3">Technology</td><td>… utility …</td><td colspan="2">Innovators & early adopters crack : “(…) a hot technology product cannot be readily translated into a major benefit (…) The enthusiast loves it for its architecture, but nobody else can even figure out how to start using it” (Moore, 2006, p. 17)</td><td>X</td></tr>
<tr><td>… complexity …</td><td colspan="2">Indirect reference</td><td>X</td></tr>
<tr><td>… complementarity …</td><td colspan="2">Early adopters & early majority crack : “…lack of support for mainstream hardware, inability to integrate it easily into existing systems …” (Moore, 2006, p. 22)</td><td>Early adopters & early majority crack : “…no established design methodology, and …” (Moore, 2006, p. 22)</td></tr>
<tr><td rowspan="3">Social Structure</td><td>… context …</td><td>x</td><td>x</td><td>X</td></tr>
<tr><td>… orientations …</td><td>Early adopters & early majority crack: “…and after a while it got a reputation as a failed attempt. And as soon as that happened, the term itself became taboo.” (Moore, 2006, p. 22)</td><td>Early adopters & early majority crack : “In large part this is because of the high degree of discontinuity implicit in their adoption by organizations (...).” (Moore, 2006, p.21).</td><td>x</td></tr>
<tr><td>… contagion …</td><td colspan="2">Early adopters & early majority crack : “And because of the early majority’s concern not to disrupt their organizations, good references are critical to their buying decisions” (Moore, 2006, p. 20)</td><td>Early adopters & early majority crack : “… the inability of the marketing effort … to lower this barrier to the early majority.” (Moore, 2006, p. 21).
“… lack of a sustained marketing effort to lower the barriers to adoption…” Moore, 2006, p. 22)
“…inexperienced sales people, (…) inappropriate channel of distribution, (…) wrong places …” (Moore, 2006, p. 39)</td></tr>
<tr><td rowspan="3">Learning</td><td>… capacity …</td><td>Early majority & late majority crack: “… the end user cannot capture the benefit” (Moore, 2006, p. 18)</td><td>x</td><td>x</td></tr>
<tr><td>… capability …</td><td>Early majority & late majority Crack: “… the end user cannot capture the benefit” (Moore, 2006, p. 18)</td><td>Early adopters & early majority crack: “…obstacles to its adoption: … inability to integrate it easily into existing systems, no established design methodology, and a lack of people trained in how to implement it.” (Moore, 2006, p. 22)</td><td>x</td></tr>
<tr><td>… costs …</td><td colspan="2">Indirect reference</td><td>x</td></tr>
</table>

Table 2-7 – Barriers of the chasm concept (Moore, 2006) mapped to the LF-model

The example of not having sufficient support for related HW and SW product for artificial intelligence in IT (Moore, 2006, p. 22), supports the variable of a lack of *complementarity* (compare section 2.3.4.1). Not being able to integrate a new technology in an existing system (Moore, 2006, p. 22) as another example supports not only the LF-model variables *complementarity* and *complexity* in the area of technological barriers, but also high efforts for switching to the new technology as *costs of learning*. Because of various existing barriers, according to Moore (1991), there is a high chance of negative WOM, which may lead to individual orientations against the new technology. This supports the according variable of *orientations* in the LF-model of MacVaugh and Schiavone (2010). With the identification of the chasm between early adopters and early majority and thus between different dynamics of early markets and main stream markets, Moore (2006) also sketches some marketing mistakes of companies failing during these different dynamics. This is represented via the *contagion* variable and the according barrier aspect in the market/industry domain of the LF-model as Table 2-7 shows. Furthermore, the added value is failed to be communicated purposefully to the different adopter categories.

In contrast to early markets, perceived risk of installing a new technology is a very important aspect in main stream markets. In comparison to innovators and early adopters, "… the goal of pragmatists is to make a percentage improvement – incremental, measurable, predictable (…)" (Moore, 2006, p. 42). If a new innovation cannot be compared to the old implementation referring to its risk and monetary evaluation, the diffusion of the innovation may be very difficult. The latter is rather represented by the *costs of learning* linked to a certain economic risk (Hess, 2007) and technological *utility* as LF-model variables. The availability of complete product solutions and its importance for the late majority and laggards (Moore, 2006) rather supports the variable of technological *complementarity* in the LF-model.

All in all, the problems mentioned by Moore to explain the existence of a chasm situation, can be mapped to barrier variables of the LF-model and support them. As the objective of this research is on the existence and interrelation of diffusion of innovation barriers, an illustrative overview is provided with Table 2-7 for the relation of Moore's identified problems for diffusion of innovation and the LF-model. As Moore (1991) focuses on the referencing of individuals within the community, most barrier aspects the author explains focus on these two domains and support various model variables (*utility* and *complexity* of a technology, *orientations* and *contagion* within a given social structure and *learning capacity*, *learning capability* and *costs of learning*). Concerning the *utility* and *complementarity* of the technology all three domains of the LF-model can be supported by Moore's (1991) explanations.

The mapping approach with the three different concepts (Moore, 2006; Hess, 2009; MacVaugh & Schiavone, 2010) shows that there are differences in the conceptual presentation and structuring of diffusion of innovation barriers. Which approach would be the most suitable for this research work is discussed in the following section.

2.4.2.3 Justification of using the LF-model as reference for barrier research

Having introduced barriers for innovation at the individual decision-making level (Ram & Sheth, 1989; Hess, 2009) and having illustrated barriers with Moore's (1991) chasm concept, the LF-model (Schiavone & MacVaugh, 2010) seems to be the more complete model. It covers macro, micro and meso levels via different domains and refers to a wider range of industries. In contrast to that, the barriers during individual decision-making (Ram & Sheth, 1989; Hess, 2009) mainly represent the phenomena at the micro level of individuals. Referring to the chasm concept, Moore's (1991) focus is the communication and referencing between individuals within a community. This is mainly referred to by the *contagion* variable of the LF-model (MacVaugh & Schiavone, 2010). Moore gives suggestions how to influence the referencing and communication activities (e.g. by diverse sales staff, opinion leaders or change agents). Therefore, the author's focus is not purely on the micro-level (the individual domain of the LF-model) but also how to make the transition to the community.

The main objectives of the research are the identification of barriers for the diffusion of innovations, patterns related to their importance and existence and the suggestion of a framework of barriers as guideline for practitioners. Referring to all three objectives, it would be very important to have a complete view of barriers for diffusion of innovation with different levels of abstraction (micro-level and macro-level) and different areas of its application. Especially in order to use a suitable framework as guideline for practitioners, it should not only consist of barriers on the micro-level of individuals but also represent phenomens of the whole industry and market. With the usage of a holistic framework to evaluate the potential existence of barriers, important decisions can be made and alternate measures can be taken at different points in time.

During the integrated product life cycle (see section 2.1.4), in which a certain technological innovation may be embedded, various decisions need to be made very early in terms of product, marketing and sales strategy but also R&D. A framework can be a helpful guideline for practioners, if it is complete and well structured. It should support the identification of barriers from the micro-levels of individual decision-making (in which a suitable marketing strategy applies) to macro-levels (in which decisions in corporate strategy may be needed). Thus, risks associated with diffusion may be evaluated and reduced.

The LF-model seems to provide a complete framework of various barriers in different categories (technology, social structure and learning). It provides a domain on the micro-level of individuals, which also represents barriers due to individual adoption decision-making (Ram & Sheth, 1989; Hess, 2009). Another domain represents aspects for a community of users and their interaction, which Moore (2006) emphasises. In addition to its domains of individuals and a community of users, it contains a third domain on the macro-level of a market/industry. This provides additional value to practitioners compared with the other two concepts regarding the macro-level perspective. The following graphic illustrates that the LF-model appears to be the more complete model, while other concepts only describe a sub-area of it.

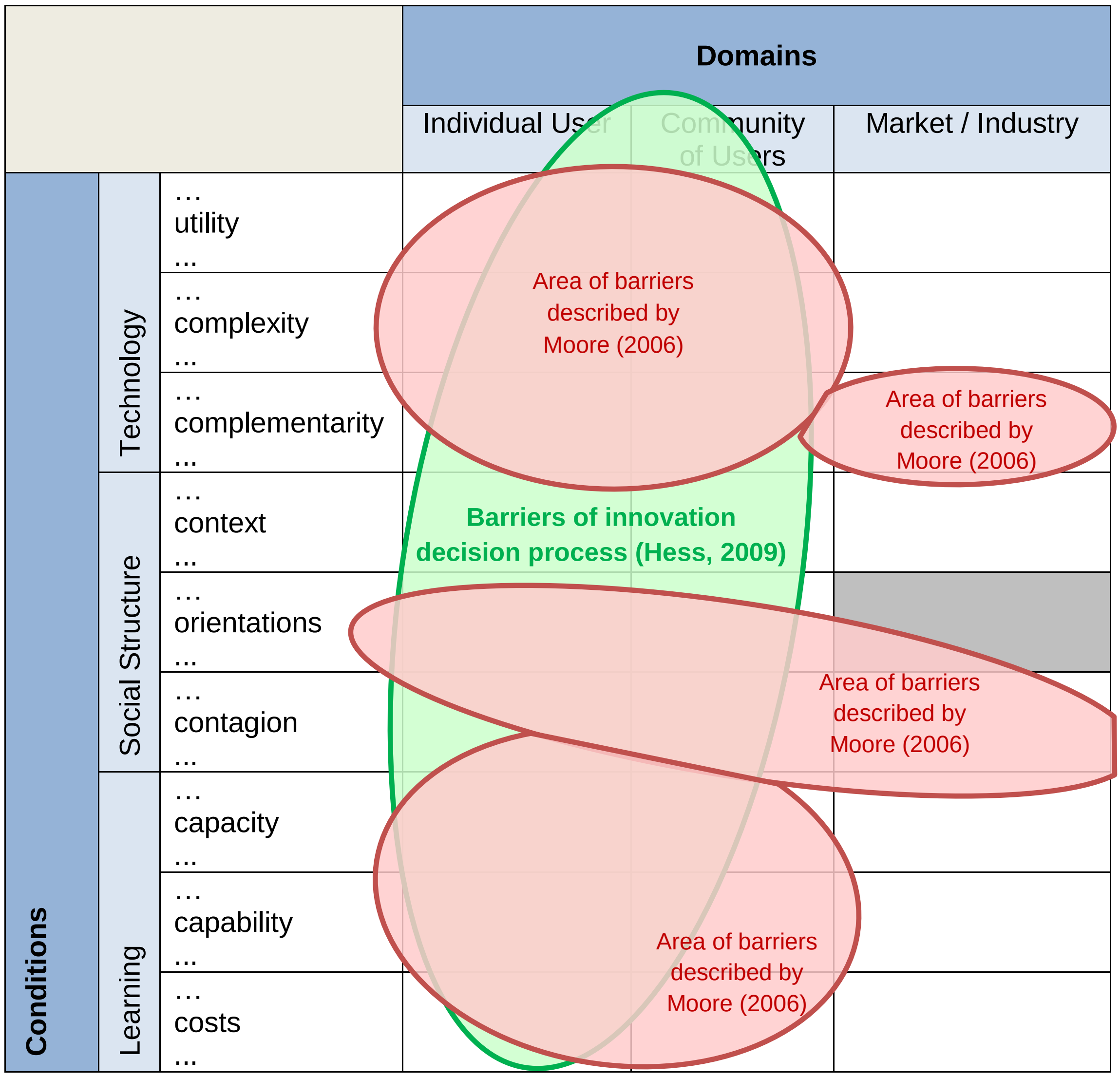


Figure 2-15 – Intersecting sets of barriers from different barrier concepts

Comparing the type of knowledge, its utilization, the supporting literature, the different findings and the limits of the different approaches, the preference is for the LF-model. Another aspect is its postulated area of application as a guideline for practitioners, which is in line with the third research objective. As this study is not limited to one major type of industry, nor does it focus on individual adoption decisions only, the LF-model of MacVaugh's and Schiavone's (2010) research provides a well-structured reference for diffusion barriers. The LF-model is therefore used during the course of this research. However, the model also comes with some limitations, which are explained in the next section.

2.4.3 Critics of model of limiting factors to the diffusion of innovation

2.4.3.1 Relations between different levels and different domains

MacVaugh and Schiavone (2010) do not present relations in their model and suggest extending their research. Their "…model does not integrate the overlapping effects of the different contexts and domains in which almost all new technology operates" (MacVaugh & Schiavone, 2010, p. 207). The main criticism about this is the simplicity of the illustration for strategic decision-making in which interdependencies should also be considered.

Each barrier aspect represents a single reason why a technology is not adopted but the barriers are not related to others. Ram and Sheth (1989) explain that usually several barriers prevent an innovation from its success.

An example of such interference can be the relation of higher technological utility with the personal orientation towards the older technology. In the innovation decision process according to Figure 2-8, the rejection of an innovation can take place even if the utility of the technology is higher than the previous technology because of personal orientations. This may be explained by overvaluing the technology used so far (Woodside, 1996; Gourville, 2005; Hess, 2009). The relation between the model variables *orientations* and *utility* is not referred to in MacVaugh and Schiavone's research.

For several barriers, which prevent an innovation from its diffusion, there would be a certain relation and co-existence. Referring to the model, the relations of the model variables and the subordinate barrier aspects can be subject for further research.

2.4.3.2 Missing technological adaptability

Allowing an effect of increasing technological performance requires either exchanging the currently installed technology or the adaptability of the innovation (Wolfe, 1994). Charters and Pellegrin (1972) describe barriers for innovation on four studies, in which re-invention or respectively adaptation is referred to. Rogers (1995) considers re-invention as the possibility for a potential adopter of modifying the innovation. The author explains several motives for re-inventions, under which some are to be considered as technical process after an adaption. Individual learning is required to adapt a new innovation to existing conditions (Rogers, 1995; Richerson, 2001). Simplification of a complex system can be an objective of an adopter when installing a system. As the installation of complex systems can require the solving of many problems, it is important that possible changes can be made at a later stage (Rogers, 1995).

Giving basic rules for an individual in the decision process to increase chances of adopting good and rejecting bad innovations, Richerson explains that "…many innovations will require a certain amount of fine-tuning to suit an individual's circumstances" (Richardson, 2001, pp. 356).

McKenna explains that today's "…emerging and evolving markets are demanding continual adaptation and renewal, not only in times of difficulty but on the heels of our greatest successes as well" (McKenna in Moore, 2006, p. xiv). McCrindle and Wolfinger (2009) refer to a new generation which is and will be used to continuous change and adaptation. Today's society with a new generation focuses on using technologies with internet-acess and high inter-connectivity (Gergen & Martin, 2012; Steinheber & Chlupsa, 2012).

The possibility of adaptation increases the probability of technology adoption (Berman & McLaughlin, 1977; Nutley et al., 2002). Cell phones and their static functionality in relation to highly adaptable smart phones are a good example to explain this aspect in today's society. Adaptability of a new technology can be an important attribute for an innovation to diffuse (Wolfe, 1994), not only in consumer electronics. For industrial goods modularity is required to reduce adaptation efforts (Baldwin & Clark, 2000; Schilling, 2000).

Apart from the importance of adaptability for consumer goods there are also other types of products applying new technologies, for which it would be important to provide certain adaptability.

Another example for the importance of adaptabiltiy of an innovation is the research of Petkova et al. (2010) illustrating the existence of several barriers for medical equipment referring to related publications (e.g. Hansen et al., 2010). As with restricted access resulting from regulations and standards an additional barrier exists that prevents local innovation adoptions in developing countries due to a lack of local adaptation (Petkova et al.; 2010; Hansen et al., 2010). Adaptability and re-design of technologies to fit to the needs of developing countries is discussed for medical devices (Petkova et al., 2010, p. 15). The absence of adaptability can influence adoption decisions and can be seen as barrier for the diffusion of a technology. Adaptation possibility increases the probability of adoption (Berman & McLaughlin, 1977; Nutley et al., 2002).

The different levels of influence as variables in the LF-model regarding attributes of the technology itself are based on Rogers's (1962) different attributes of an innovation. Critics on the original research of Rogers (1962) by Wolfe (1994) suggest adaptability as an additional attribute of a technological innovation, which influences its adoption. Adaptability aspects may also be perceived as general utility of a technology but as this question is not discussed in the research of MacVaugh and Schiavone (2010), it seems that comparable critics may apply to the model as the ones of Wolfe (1994) on the research of Rogers (1962).

2.4.3.3 Limits of the model regarding environmental awareness

With global warming, climate change, shrinking energy sources and the need for alternatives (e.g. Gillis, 2011; Bauer et al., 2009; Kondratyev, 1998, Broder, 2011), an increased environmental awareness in society and the environmentally-friendliness of a new technology can influence adoption decisions. The LF-model shows some limits concerning such aspects.

Most environmentally-friendly technologies experience competitive advantage. One aspect is a high potential for saving costs in the long run (Ahmia, 2009; Steinheber, 2012). Kumar (2010) explains the relation of innovativeness and its dependency from energy prices as extremely constrained. Energy costs and other measurable environmentally-friendly aspects may be regarded as technological *utility* because of energy consumption (Tischner et al., 2000; Attari et al., 2010; Kumar, 2010), material and space reduction (Steinheber & Gerstl, 2012) and modularity for reduced adaptation (Baldwin & Clark, 2000; Schilling, 2000).

In addition to measurable higher utility, Ahmia (2009) refers to environmental awareness by explaining higher perceived utility and cost-ratio (Zeithaml, 1988; Cramer & Tukker, 1998; Yim, 2007). Nevertheless, the utility is strongly driven by its functionality, being part of the model.

MacVaugh and Schiavone point out that ‘green’ technological utility may not be the driving force of its adoption. On the example of electric cars and advancements in electric engine and battery design, they explain that petrol engine as older technologies may not be replaced as the focus is on overall effectiveness of an automobile as complex product (Moreau et al., 2001; MacVaugh & Schiavone, 2010). The model represents this as part of the variable of *complexity* as technology focused condition.

However, as an innovation also needs to be sustainable (Porter & van der Linde, 1995; Klostermann & Tukker, 1998; Yim, 2007; Parthasarathy, 2011). Our society with increased environmental awareness also follows sustainable motives (Stern, 1999). Technology attributes represent rational aspects but decision makers might subconsciously favour greener options (Stern, 1999; Vandenbergh et al., 2011). That an adoption makes sense to individuals may originate from individually developed patterns (Seligman, 2006) which MacVaugh and Schiavone refer to as grounding process for technology evaluation. Patterns may include environmental awareness.

There is a need for information about sustainability (Sakmar et al., 2011; Steinheber & Gerstl, 2012) and a product's carbon footprint (Wackernagel & Rees, 1996; Laroch et al., 2001; Grießhammer & Hochfeld, 2009; Dresen & Herzog, 2009; Schmidt, 2010; Steinheber, 2012) and its measurement (SGS, 2011; ISO, 2011, 2012) to explain the relation between environmental and economic aspects of a new product or technology. Adoption decisions might also be related to such information (Wiedmann & Minx, 2008; Gardner & Stern, 2008; Günther & Stechemesser, 2010 and Vandenbergh et al., 2011). Communities and potential adopters need explanations of sustainable aspects of a product innovation.

The so-called 'green marketing' has been applied lately to market and sell technological innovations by addressing green selling propositions (Laroch et al., 2001; Polonsky, 2005; Grunday & Zaharia, 2008; Belz & Peattie, 2009; Horne, 2009; Singh, 2010 and Cronin et al., 2011). One reason is a higher achievable selling price (Gottlieb et al., 1995 and Laroch et al., 2001). However, environmental awareness in today's society is also misused by overstating related claims referred to as 'greenwashing' (Gottlieb et al., 1995; Blumenstyk, 2003; Ramus et al., 2005; Vos, 2009; Horne, 2009). Green marketing can be a facilitating factor (Cronin et al., 2011) but can also be a barrier if applied in a wrong way depending on the industry environment, as potential adopters can get suspicious and may show a backlash (Peattie & Crane, 2005).

In conclusion, the absence of environmentally-friendliness of a new technology, the lack of measurable criteria and missing information for sustainability or exaggerated marketing as greenwashing may also influence adoption decisions and thus the diffusion of an innovation. The model variables show limitation in representing these aspects. In case a technological utility is 'green', additional aspects as the perception of its complexity may be a limiting factor for its adoption. Apart from the technology levels of influence as LF-model variables, more aspects relate to the social structure e.g. patterns concerning the perception of environmental awareness. Barriers described as personal orientations may not sufficiently describe the importance and the different effects of the changed environmental awareness of today's society. The social structure levels of influence may touch aspects of environmental awareness but do not put a major focus on. Therefore, it may be considered within the model because innovations might have to face barriers related to that area in the individual, community and market/industry domain.

2.4.3.4 Industrial orientations as gap in the model's macro-domain

The LF-model by MacVaugh and Schiavone (2010) might be perceived as incomplete due to an empty cell as a grey spot. The model variable of *orientations* describes limiting adoption/diffusion barriers in the domain of individuals and the domain of a community of users but not in the macro-domain of a whole market or industry. MacVaugh and Schiavone (2010) leave this aspect blank, because in their opinion a market by definition needs to have a positive orientation towards a technology. The authors explain that orientations would not exist on the macro-level of a complete industry or market. With profit-making as driving force, an industry would be oriented towards a technology (MacVaugh, 2012).

Assuming that a technology is mainly subject for one market or industry, the explanations of MacVaugh and Schiavone may be convincing. It is valid to question their argumentation by considering a technology as being subject for more than one industry or market. One industry might see a very good business opportunity in a market whereas another might not expect good results and therefore may not push for the technology. This may happen in network industries, as literature about the introduction of a new broadcasting technology shows (Goldhammer et al., 2008). An orientation of a whole industry is currently not considered in the area of social structures as part of the model.

An example can be given related to the adoption of solar energy technology. Margolis and Zuboy (2006) investigate different non-technical diffusion barriers, of which most are also represented by the LF-model. However, they also explain that missing participation of stakeholders and industry community and those related to the industry is hindering the diffusion. Different stakeholders within and adjacent to the energy industry would not participate to make a change possible. This barrier is difficult to place within the framework of MacVaugh and Schiavone. It may be seen as differing orientations towards the new technology within the market or industry among different stakeholders.

Apart from the mentioned example in the solar industry, several technologies exist, which may be subject for adoption in different markets, e.g. in the automotive industry, the consumer equipment industry, telecommunication or the broadcasting industry. One market or one industry may be in favour of the new technology whereas another market or industry is not oriented towards the technology in the same way. To be able to replace an old technology which might face a 'lock-in' situation (MacVaugh & Schiavone, 2010, p. 200) e.g. in network industries, collaboration would be necessary for a successful technology introduction.

The assumption of having various industries and markets, in which a new technology is introduced, seems not to be considered in the model. As the LF-model does not consider this as limiting barrier constituting to the model variable of *orientations*, an extension of the macro-domain of a market/industry can be considered.

2.4.3.5 The phenomenon of leapfrogging related to technology generations

Leapfrogging describes a phenomenon occurring when there are multiple product generations (Mahajan & Muller, 1996). Potential adopters of the second generation might rather adopt the latest generation of a product with enhanced technological features (Mahajan & Muller, 1996) or wait for its availability because it is already in reach. Therefore the decision for a second or third generation technology can either result in adoption of the second generation or by a later adoption of the third generation (Bardhan & Chanda, 2007).

The information about the availability of new generations is widely accessible online. With the dominance of online forums and group discussions in social media (Steinheber & Chlupsa, 2012), anticipating or actually knowing the availability of technologies of a next product generation can be a barrier for the current generation.

Thus, the adoption decision for the new technology in the second generation product may not be made as another technology is already under discussion. A technology upgrade from an old technology might be decided on without considering the currently available intermediate technology (Bardhan & Chanda, 2007).

MacVaugh and Schiavone (2010) do not discuss this phenomenon with the LF-model. It only considers an orientation towards an older technology by a community of users. An orientation of an individual or a community of users may also be towards and even newer technology already under discussion. This may be seen as barrier as well.

2.4.3.6 Theoretical nature of the LF-model

The LF-model of MacVaugh and Schiavone is based on a detailed literature overview (MacVaugh & Schiavone, 2010, pp. 210). According to the authors this historic data on technology non-adoption is compared to existing theory for the development of the model. The authors underline that with the literature about different examples of non-adoption there is no evidence for the presented limiting factors as barriers causing non-adoption.

The model is theoretical in nature, because it is based on a literature review. The authors admit that it would require quantitative study to verify its structure and meaning (MacVaugh & Schiavone, 2010).

Apart from the authors' recommendation to research interdependencies and regularities, empirical data may support the model regarding different levels of importance of barriers for practitioners. Researching relations and quantitative model verification would provide a basis for deepening their research empirically.

2.4.4 Research Gap and conceptual development

2.4.4.1 Examination of most important barriers for the diffusion of innovation

One of the main research objectives is the identification of those barriers, which are most critical for preventing an innovation from its diffusion. MacVaugh and Schiavone's (2010) LF-model provides a huge range of very different diffusion and adoption barriers. Nevertheless, the model comes with limitations. As it is mainly based on literature and case examples of the past, it may not sufficiently reflect present circumstances such as the need for technological adaptability, the environmental awareness of society and effects of the early availability of information about a technology. The model also seems to show an inconsistence in the macro-domain, in which it shows an empty cell and no further consideration is provided.

Adding value to the existing research would be the identification of most important barriers from today's point of view. Some barriers might modify or extend the LF-model. By applying or extending the LF-model, variations of their importance and relevance can be researched and would add value to the model.

Another limitation of the model is the missing integration and discussion of overlapping effects of diffusion barriers, represented by model variables. One might strongly be dependant from another barrier. The outstanding discussion of relations would close a research gap which is why the authors, MacVaugh and Schiavone, recommend performing an examination on interdependencies of the model variables. Empirical data gathering from experienced industry experts can give additional information on importance and existence of barriers.

2.4.4.2 Occurring patterns of diffusion of innovation barriers

Another objective is to identify patterns for existing barriers which may cause problems for diffusion of innovation. While Moore's (1991) investigations are mainly based on the IT industry of the late 1990s, MacVaugh and Schiavone (2010) give case examples of different industries. The question occurs whether the existence and importance of barriers are comparable for different types of industries. Empirical data from industry experts may give an answer on variances in the importance and existence of diffusion barriers in different industries. Further differences may exist between developed and emerging countries or different types of good. Outlining patterns of barriers for different industries, regions and products would help practitioners to focus on the most important ones according to their context. This would also provide a more suitable applicability of the model.

Empirical data gathering might help to find a pattern of the existence and importance of barriers. MacVaugh and Schiavone (2010) explain that their model is based on historic literature referring to different case examples. It is of theoretical and exploratory nature and would need quantitative study for verification.

Extending the theoretical research by empirical data and its analysis would add valuable knowledge to the research of MacVaugh and Schiavone (2010) in terms of the validity and applicability of the model in different contexts. The investigation of patterns together with further research on existence, variations and interdependencies of barriers for innovations would extend the current knowledge.

2.4.4.3 A complete framework or model of diffusion barriers for practitioners

A framework of barriers like the one of MacVaugh and Schiavone (2010) should be as simple but also as complete as possible for its application in practice. The main conclusion from the research and model of MacVaugh and Schiavone (2010) is that practitioners should consider a wide variety of factors, which may be limiting the adoption of a certain technology.

Such a model can be applied in practice to different business organizations, for example, business development, strategy, product and marketing management. This target group needs guidance in decision-making on product or technology strategies taking into account the existence of barriers for diffusion of innovation as potential risk. They may ask themselves, which barriers endangering an innovation to diffuse need to be double-checked e.g. when writing a new business plan before R&D or working out a marketing. Assistance can be given by a framework like the LF-model for decision-making and risk evaluation. In a wider sense, a framework could also be used as a tool that helps to establish marketing and sales methods to overcome barriers diffusion of innovation.

Because of some existing critics and needs for further discussions concerning MacVaugh and Schiavone's (2010) LF-model, research efforts need to be performed for potential improvements or clarifications.

With the objective of providing a valid framework of barriers for practitioners, the gap between researched barriers from historic data and important contemporary barriers should be closed. The LF-model as most suitable framework demonstrates some limitations that call for further investigation.

Researching the existence, variations, interdependencies and communalities of barriers could provide additional value to the model and potential improvements. The identification of patterns would add up to the approach of both, generalization and tailoring for different types of industries, products and regions regarding the applicability of such a framework by practitioners. How the research gap could be closed by researching hypotheses is explained in the following section.

2.4.4.4 Formation of hypotheses relating to research questions and research gap

The previous three sections introduce the identified gaps based on the literature review, which can be linked to the research objectives. This section describes the development of concepts to follow the main research questions (see section 1.2.2) by researching hypotheses. The research question, whether existing models and frameworks correlate, is addressed within this chapter based on three major concepts (see sections 2.4.2.1 and 2.4.2.2). The other three main research questions are addressed by empirical data gathering. Therefore, the following paragraphs address the main and additional research questions (see section 1.3) by suitable hypotheses.

The most important research question stated at the beginning is which barriers are the dominating contemporary barriers for the diffusion of innovation. Existing literature does not give any prioritisation of contemporary barriers. As section 2.4.4.1 describes, the LF-model of MacVaugh and Schiavone (2010) does not give any indication on which barrier has more significance and which has less. One research question to follow is also whether several barriers lead to non-adoption or whether there is one dominating barrier. Also, the other frameworks such as those by Ram and Sheth (1989) and Hess (2009) do not rate barriers according to their significance. The section also refers to research questions regarding the sufficient representation of diffusion barriers concerning recent changes in the business environment (see sections 2.4.3.2 to 2.4.3.5), such as easy access to information by the current generation (see section 2.4.3.5). Considering the diffusion barriers described in the literature as part of this chapter and potential additional barriers not considered as part of the LF-model by MacVaugh and Schiavone (2010), it is necessary to investigate whether there are variations among the barriers regarding their importance and significance to answer the research questions mentioned.

Section 2.4.4.2 describes a research gap regarding the contextual significance of diffusion barriers by questioning whether they are comparable within different industries or whether there are differences between different economies or different types of technologies. Variations may exist depending on such contexts.

The previous section (section 2.4.4.3) describes the needs for practitioners, following the research questions. Which barriers have to be considered as potential risks in a business plan? Which are those that could be addressed before launch and which are those to focus on? To address this need, context-dependant variations among barriers have to be researched. Additionally, existing gaps in the LF-model may be closed (see section 2.4.3.4) if variations show a high importance for barriers that may fill a gap in the LF-model. The following illustration (Figure 2-16) shows the types of variations to be researched.

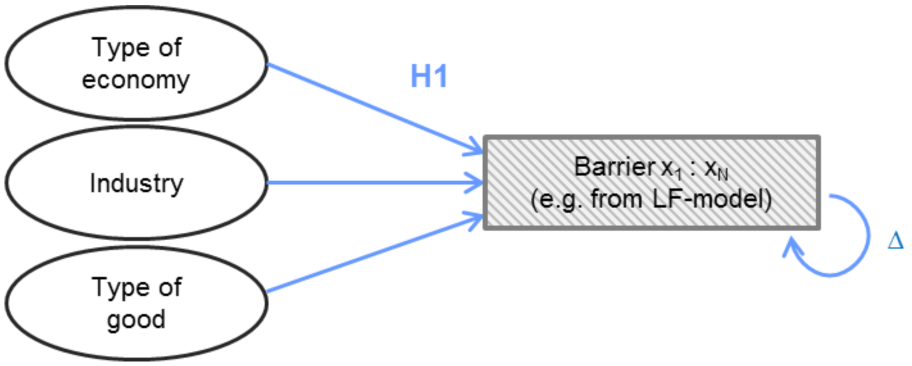


Figure 2-16 – Hypothetical variations among and between diffusion barriers

As MacVaugh and Schiavone (2010) describe, their LF-model is of a theoretical nature and researching variations with empirical data would add to existing knowledge (see section 2.4.3.6). As there are various contexts upon which the importance of barriers depends (see white circles of Figure 2-16) and, in addition, variations may exist among diffusion barriers (see blue round arrow of Figure 2-16), a general hypothesis can be formed to address the research questions and all three research objectives:

H1: There exists variation in the importance of influencing barriers limiting the diffusion of an innovation.

Hypothesis H1 is the primary hypothesis of the research and also answers the main research question on whether barriers in one industry are comparable to barriers existing in other industries, for which no profound indications are given in the existing literature regarding barriers. As the hypothesis describes different variations, several subordinate hypotheses are used during the course of this investigation following the illustration of Figure 2-16, such as the research of variations among barriers regarding their importance and significance without and within a specific context such as an industry.

The second research objective, describing patterns of barriers, also relates to a research question of existing interdependencies among barriers (see section 2.4.4.2). The authors of the LF-model also describe the potential existence of interdependencies as a limitation of their model (see section 2.4.3.1). MacVaugh and Schiavone (2010) do not present relations between the main variables of the LF-model. Such a relation can be between a higher technological utility and *orientations* towards the older technology. The following illustration (Figure 2-17) shows the relation of any two variables (x and y) of the LF-model by MacVaugh and Schiavone (2010).

Figure 2-17 – Hypothetical correlations between LF-model variables

Relations, e.g. between the LF-model variables of *orientations* and *utility*, are not referred to by MacVaugh and Schiavone (2010). The relationships may also be of different strengths which indicate patterns within the model. To investigate the relations as suggested by the authors of the LF-model, the following hypothesis was researched:

H2: There exist correlations of different strengths among the barrier variables of the LF-model.

Quantitative research can allow a comparison of relations and associations between technology-related barriers and barriers related to the social structure. Furthermore, the values of the strengths of correlations can give an orientation on their interdependency regarding potential extensions of the model. This is described in the next paragraphs.

One research question is whether a changed environmental awareness in society and the need for technological adaptability represent contemporary diffusion barriers with a significant importance compared to the barriers described in diffusion of innovation research. Assuming their existence, the first research objective and also section 2.4.4.1 describe the need to identify the most important barriers, among which those aspects might also appear. Following the second research objective and referring to section 2.4.4.2, variations can be researched considering those that are not described in the literature. Those aspects can be explored via hypothesis H1 as described earlier. As section 2.4.4.3 describes, the LF-model may be extended by incorporating new, contemporary barriers.

The description of the need to consider technological adaptability (see section 2.4.3.2) relates to the research question of the impact of different needs of the current generation. The consideration of a lack of adaptability as a contemporary barrier is a research question to be answered according to the literature analysis. Criticisms of diffusion of innovation research (Rogers, 1962) by Wolfe (1994) suggest that adaptability should be considered separately. MacVaugh and Schiavone's LF-model (2010) does not state the adaptability of a technology as a model variable directly related to the technology. The technology-related barrier variables of the LF-model may already consider adaptability. A candidate for such a LF-model variable is *utility* (see section 2.4.3.2), which is illustrated as correlation by the following figure (Figure 2-18).

Figure 2-18 – Hypothetical correlation of utility with technological adaptability

The *utility* of a technology may already cover aspects of upgradeability and adaptability, but literature states adaptability separately (Wolfe, 1994; Bardhan & Chanda, 2007). Therefore, the following hypothesis is applied to investigate whether the LF-model variable *utility* sufficiently represents aspects of adaptability.

H3: There exists a correlation between the adaptability of a technology and the technology's utility as a barrier variable in the LF-model.

To research the need of considering adaptability aspects as separate barriers, hypothesis H1 is applied but hypothesis H3 is explored additionally regarding a potential extension of the LF-model. The strengths of correlations researched via hypothesis H2 can be used for comparison.

Similar to the adaptability of a technology as a contemporary barrier subject to extend the LF-model, the aspects of environmental awareness are considered following the same main research question. However, literature (see section 2.4.3.3) describes those aspects with minor importance in comparison to other barriers (MacVaugh & Schiavone, 2010). Additional research questions are described with the first research objective (section 1.3.1) but also regarding guidelines for practitioners, questioning how to best launch new technologies under that circumstance of the current society (section 1.3.3). Potentially extending the LF-model by barrier aspects forming a variable for environmental awareness, the question arises as to which of the three main condition areas of the LF-model may be applied. Green argumentation and the perception of environmental friendliness may influence the diffusion of innovation. The literature section shows that the phenomena of environmental awareness may rather be categorized into social conditions. Consequently, the following Figure 2-19 illustrates potential relations between already existing LF-model variables of the social structure and environmental awareness as a barrier.

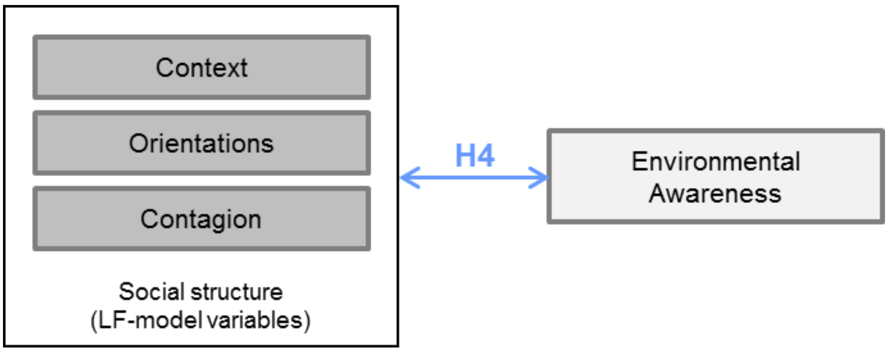


Figure 2-19 – Hypothetical correlation of social with environmental awareness

The LF-model variables of social structure conditions may implicitly already incorporate environmental-friendly aspects. Therefore, the following hypothesis is used to be researched in addition to hypothesis H1:

H4: There exists a correlation between environmental friendliness and the barrier variables of the social structure in the LF-model.

To investigate the need of considering aspects of environmental awareness as separate barriers, hypothesis H1 is applied but hypothesis H4 is researched additionally to be able to compare the strengths of correlations, which are studied researched via hypothesis H2.

The evaluation of all hypotheses is therefore used to potentially extend the LF-model in response to the criticisms discussed in 2.4.3. However, hypothesis H1 represents the most important hypothesis as all objectives are aligned with it. The major research questions can be approached verifying hypothesis H1. An overview of the main hypotheses stated referring to the objectives of this study is presented in the following table.

Hypothesis number	Hypothesis description	Objective		
		1	2	3
H1	There exists variation in the importance of influencing barriers limiting the diffusion of an innovation.	**X**	**X**	**X**
H2	There exist correlations of different strengths among the barrier variables of the LF-model.		X	
H3	There exists a correlation between the *adaptability* of a technology and the technology's *utility* as barrier variable of the LF-model.	**X**	(X)	X
H4	There exists a correlation between *environmental friendliness* and the barrier variables of the social structure in the LF-model.	**X**	(X)	X

Table 2-8 – Allocation of hypotheses to research objectives

The allocations of Table 2-8 marked in bold represent the main focuses of the hypotheses to address the research objectives. The allocations of Table 2-8 in brackets illustrate that the second research objective is only addressed partially via the strength of correlations. Variations are mainly researched via hypothesis H1.

This section forms hypotheses, which relate to the literature review. Based on the research objectives and related questions, research questions arose from the literature review. Besides questioning the existence of multiple variations, the question also arises as to whether additional barriers are already represented by LF-model variables or should rather be incorporated into the model. This is researched via suitable hypotheses.

2.5 Summary of implications based on literature review

As part of this chapter, background literature and basic models of diffusion of innovation research are introduced. Background literature is considered concerning basic models and methods used during the course of the research, such as types of innovation, and the integrated product life cycle to locate the need for decision-making to reduce the risk regarding diffusion barriers.

Important findings of diffusion of innovation research are summarized as the main body of knowledge. Especially those findings are illustrated, which seem to be important concerning their usage and their appearance in literature as scientific basis.

This chapter considers knowledge about diffusion barriers and approaches for structuring barriers as main research discipline. Therefore, the most important barriers and models are outlined. The focus is put on a framework of individual adoption barriers during the innovation decision process (Ram & Sheth, 1989; Hess, 2007), barriers as reasons for the existence of cracks in the bell curve as chasm concept (Moore, 1991, 2006) and barriers from the model of limiting factors to the diffusion of innovation (MacVaugh and Schiavone, 2010).

In a further section, the three different concepts are compared with each other. The concept of Moore (2006) and of Hess (2007) and its underlying literature support the LF-model of MacVaugh and Schiavone (2010) only partially. The LF-model is chosen as further reference because of its completeness, its applicability and its nature as a guideline for practitioners.

The limitations of the LF-model are discussed critically. Among its limitations, an empty spot in the LF-model is criticized and further barrier aspects related to technological adaptability and environmental awareness are discussed. Another limitation presented is the theoretical nature of the model. Empirical data gathering can add value. These and other aspects are introduced as remaining research gaps. The following chapter introduces the research methodology, with which the gap can be closed.

3. Research methodology

This chapter describes the research methodology used to collect and analyse data related to research objectives. The chapter justifies the chosen position in research philosophy and gives an explanation of why subsequent methodologies were chosen. Following sections detail the research methodologies, the data gathering methods and give an overview on how the main objectives were achieved within the research.

3.1 Research philosophy and mixed-methods approach

The literal meaning of philosophy as the "love of knowledge or wisdom" (Blackburn, 2007, p. 275) already gives the impression that a PhD describes a specific knowledge contribution area, a research focuses on. It is important to show a good understanding of research philosophy for choosing suitable research methods. Therefore, this section describes standpoints of philosophical paradigms and their methodology in order to give an overview of what kind of research could be done and why it was decided upon.

Bryman (1988) explains that both qualitative and quantitative research approaches are used for collecting data depending on the research objectives and questions. Qualitative and quantitative approaches cannot be totally and always separated (Kelle & Erzberger, 2000). Because of their compatibility, a combination is suggested as 'mixed-method' research (Brymann, 1988; Brewer & Hunter, 1989; Tashakkori & Teddlie, 1998; Kelle & Erzberger, 2000). Such a combination according to Mayring (2001) can be achieved under various conditions, such as a combination of one or more qualitative phases with one or more qualitative phases of the research design. The possibility of applying complementing methods is an advantage of the mixed-methods research (Creswell, 2003). Also, the use of both qualitative and quantitative methods can be beneficial for generalizations (Tashakkori & Teddlie, 2010). Apart from the possibility of triangulation of alternate results (Creswell, 2003), a broader set of research questions can be addressed (Migiro & Magangi, 2011).

However, in social sciences the idea exists those quantitative and qualitative researches are contradictory (Bryman, 1988; Sechrest & Sidani, 1995). Tashakkori and Teddlie (1998) refer to it as a 'war of paradigms' between positivism and constructivism. The authors try to give an overview of major philosophical paradigms referring to mixed-methods approaches, as the following table (Table 3-1) illustrates.

Paradigm	Positivism	Post-Positivism	Pragmatism	Constructivism
Epistemology Relationship between reality and researcher; Nature of knowledge	Objective point of view. Dualism of Knower and known.	Modified dualism. Findings probably objectively "true".	Both objective and subjective points of view.	Subjective point of view. Knower and known are inseparable.
How do we know what we know?	Findings are true. Theory is verified	Findings are probably true.	Findings have different interpretations	Findings are created, Theory is generated
Axiology Place of value of the research	Inquiry is value-free.	Inquiry involves values, but they may be controlled.	Values play a large role in interpreting results.	Inquiry is value-bond.
How is gained knowledge used?	Theory verification		Problem-centred, Real-world practice oriented theory interpretation	Theory generation
Ontology Study of being; Reality, the researcher investigates based on assumptions	Naive realism	Critical or Transcendental realism.	Accept external reality. Choose explanations that best produce desired outcomes.	Relativism
What is reality and what is knowledge?	Knowable / discoverable	Knowable through probabilities	Considering Plausibility	Constructed in people's minds with people's values
Methodology Technique of investigation	Quantitative	Primarily Quantitative	Quantitative and Qualitative	Primarily Qualitative
How is knowledge gained?	e.g. experiment	e.g. survey	several methods	e.g. interviews
Logic	Deductive	Primarily Deductive	Deductive and Inductive	Inductive

Source: Adapted from Tashakkori and Teddlie (1998, p. 23); also from Creswell (2009)

Table 3-1 – Candidates of paradigms for research philosophical positioning

A controversially discussed aspect relates to the question of which philosophical paradigm fits best to a mixed-methods research (Teddlie & Tashakkori, 2009; Migiro & Magangi, 2011). For a mixed-method approach, facets of both the paradigm of positivism and the one of constructivism are combined (Teddlie & Tashakkori, 2009).

Teddlie and Tashakkori (2009) explain that 'pragmatism' seems to fit best for mixed-methods as a set of different ideas is evaluated by different approaches. The authors give high importance to the influence of research questions and objectives in comparison to methodology or underlying paradigm. The following three paragraphs explain how the research can be positioned regarding epistemology, axiology and ontology.

Considering very different participants in the research, reasons for an unsuccessful diffusion can be evaluated from epistemological, objective and subjective points of view (Cline, 1998). Relatively objective aspects are sales numbers which give proof of an unsuccessful market introduction. With the use of frameworks which are less deterministic (Nutley et al., 2002) and which consist of several barriers whose meaning may be different depending on the context, the research also consists of subjectively interpretative orientations. With the objective of providing patterns and frameworks for practitioners in their contexts, it is important to consider different interpretations of the findings, although some findings might probably be true and generalizable. The importance of both views, objective and subjective points of view, indicate the paradigm of pragmatism (Teddlie & Tashakkori, 2009).

This study contemplates contextual values by interpreting results, considering differences in business and industry and in cultures of economic regions. For the research objective of providing a framework considering different values and contexts, a pragmatic approach seemed to be suitable regarding axiology (Creswell, 2009). Explanations were chosen to best produce the desired outcome regarding the research objective of providing a guideline for practitioners.

Questioning the truth, critical realist approaches are based on the fact that the form of reality is a result of social dependant perception (Saunders et al., 2007) and is mainly driven by individualistic views of social actors, which are also involved in the knowledge derivation process of this research. However, following the research questions and objectives of finding patterns for barriers which may be useful for practitioners, a pragmatic approach is preferred. Although the ontological aspects discussed give ideas for critical realism, this study gives explanations to best produce the desired outcomes regarding the research objective (Tashakkori & Teddlie, 1998) of providing a context-dependent less deterministic guideline for practitioners.

The interpretation of the results pragmatically considers theory application and interpretation related to the external situational context of the real-world, which indicates ‘pragmatism’ as a philosophical paradigm (Teddlie & Tashakkori, 2009).

Teddlie and Tashakkori (2009) explain that the paradigm of pragmatism seems to fit best with mixed-methods, as a set of different ideas is evaluated by different approaches. This approach can be used for both testing and verifying existing knowledge and generating new knowledge (Meredith, 1998). A pragmatism position matches the research objectives very well regarding epistemological and ontological positioning. Teddlie and Tashakkori (2009) point out that pragmatism is rather intuitive without positioning:

“…study what interests you and is of value to you, study in the different ways in which you deem appropriate, and use the results in ways that can bring about positive consequences within your value system.”

(Tashakkori & Teddlie, 1998, p. 30)

As Teddlie and Tashakkori (2009) explain the importance of the actual research questions and objectives, in comparison to the underlying paradigm. As the paradigm of pragmatism matches very well with the research objectives for this study, a mixed-methods approach is applied, taking a position towards the paradigm of pragmatism due to the possibility of following the introduced research objectives.

Following the research objectives of this study, a mix of two methods is chosen in order to complement each other (Creswell, 2003). This investigation pragmatically follows a mixed-methods approach taking advantage of both research methods.

Applying qualitative and quantitative methods can support generalizations (Tashakkori & Teddlie, 2010) which are set out to be provided by a framework for practitioners. As Creswell (2003) and Migiro and Magangi (2011) explain, a further advantage is that it allows triangulation between the results of the different methods. This is also supported by Johnson and Onwuegbuzie (2004) who describe its pluralism as a key feature of this research approach. They explain that a mix of methods often provides superior research in comparison to a single research method. Migiro and Magangi (2011) argue that a stronger evidence for a conclusion can be provided, if results are combined and integrated.

With a number of research questions provided in section 1.2.2, a mixed-methods approach was regarded as being more suitable, as the questions can be answered from a broader perspective both with deep insights and the approach of generalizing (Migiro & Magangi, 2011). According to Migiro and Magangi (2011) and according to Johnson and Onwuegbuzie (2004), the different methods can be used for different purposes or different research objectives. This will be discussed in the following paragraph.

In contrast to epistemology, axiology and ontology, the research methodology describes an area of tools and techniques for researching. The benefits of a mixed-methods approach as well as the advantages of the chosen type and order of methods are discussed in the following section. In the subsequent sections the research strategy and methodology are described.

3.2 Research Strategy

3.2.1 Discussion of mixed-methods approach

Having discussed the paradigms of research philosophy, suitable techniques for investigation are presented. The research strategy of mixed-methods seems to be most suitable and was thus chosen. A table is used to illustrate how the research objectives and subordinate research questions may require different methods (Table B-1). To verify the theoretical model of MacVaugh and Schiavone (2010), initial exploratory research via a qualitative approach helps to start data gathering within a certain context.

The objective of the mixed-methods approach is to come to a suitable result as contribution to knowledge from a qualitative study and a quantitative research approach. Data collection and data analysis were then based on multiple methods.

In this mixed-methods approach, an initial qualitative research is applied to approach certain ideas of why a specific innovation faces a tough challenge to diffuse. With the result of an initial case study, a survey gives the possibility for further research to generalize (Creswell, 2003) and to develop research instruments (Steckler et al, 1992).

Mixed-methods have the advantage of complementing each other as the results from one method can be evaluated by applying the other (Creswell, 2003). The sequential application of qualitative, followed by quantitative methods can be helpful for generalization as Tashakkori & Teddlie (2010) explain,and as does Creswell (2003):

“Sequential procedures, in which the researcher seeks to elaborate on or expand the findings of one method with another method. This may involve beginning with a qualitative method for exploratory purposes and following up with a quantitative method with a large sample so that the researcher can generalize results to a population.”

Creswell (2003, p. 16)

Results of qualitative research can be confirmed and generalised following quantitative research methods (Creswell, 2003). This combination is often suggested (Lobe & Vehovar, 2009) and applied in behavioural research (Clark et al., 2012; Bahls, 2013).

Creswell (2003) and Migiro and Magangi (2011) explain more benefits from using mixed-methods such as the possibility of triangulation. According to them, it is also beneficial to use different methods for different purposes of the research. Mixed-methods research provides the possibility of addressing a broader set of research questions as it allows deep insights and the possibility of generalizing; it can also provide a stronger evidence for a conclusion by the combination and integration of results (Migiro & Magangi, 2011).

Although the mixed-methods approach seems to be more complex and can be more expensive and time consuming, it brings several advantages regarding the objectives of the research (Migiro & Magangi, 2011). Case study research using interviews with individuals of a certain industry allow deeper insights on the existence of barriers related to one specific technology in comparison to the survey results. Nevertheless, a survey directed to different industry and technology fields can increase the generalizability of the research results. A mixed-methods approach can provide both.

Different designs can be applied for a mixed-methods approach (Migiro & Magangi, 2011). In contrast to explanatory, the most suitable design for mixing these methods for this study was exploratory, as initial data analysis can evolve into the formation of model variables to be evaluated via a survey.

The initial case study research allows getting important impressions on the key issues related to diffusion barriers with the example of digital radio. The goal of a subsequent survey as quantitative research was to evaluate and generalize these issues for several industries with a larger sample size. Triangulation of literature and the use of the two different data collection methods guaranteed a good validation of the conclusion. This approach is also in line with the research objectives. In addition to the identification of barriers, another objective is to develop a guideline for practitioners from different industries. A pattern may evolve from the survey on industrial fields or economic region and is the basis for the development of a framework, which should turn out to be helpful for practitioners.

In addition to the implementation and prioritization of data gathering and the integration of results, additional steps are needed for a mixed-methods approach (Tashakkori & Teddlie, 1998; Creswell, 2003; Migiro and Magangi, 2011). The integration and mixing of both, methods (see section 3.2.5) and results (see section 5.1) needs to be performed. Aspects emerging from the qualitative research method are transformed into a suitable format for subsequent comparison with quantitative results.

This section explains how a mixed methodology was applied as research strategy. Such an approach is neither completely inductive nor deductive, as the following section illustrates.

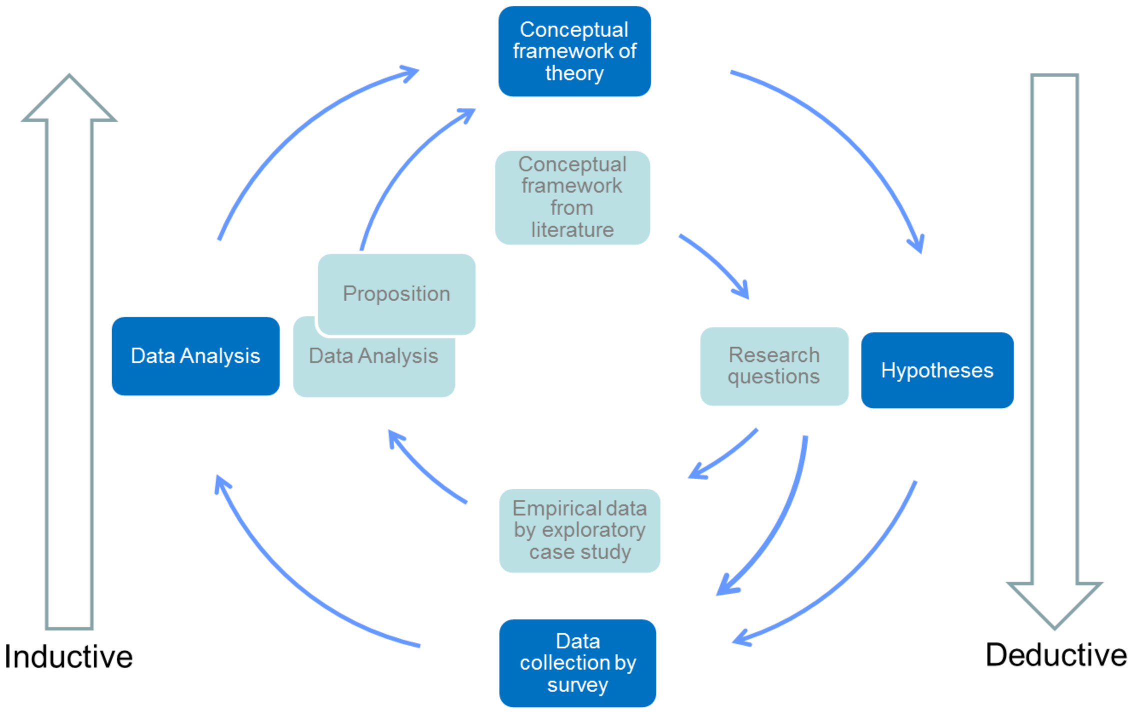
3.2.2 Inductive versus deductive research

Like the distinction between qualitative and quantitative research strategy, the distinction between inductive and deductive research can also not be made that easily. Rudestam and Newton (2007) illustrate this by a ‘research wheel’ outlining that the research process itself is not necessarily linear. It seems to be a ‘perpetuum mobile’ of scientific research, as its nature continuously strives for more theory to be researched.

Creswell (1994) mentions that for the existence of extensive literature it is more likely to focus on deduction. Existing literature explains several models about diffusion of innovation; nevertheless there is a lack in focusing on the existence and differences in the importance of barriers for diffusion of innovation via frameworks and models.

With an inductive approach, theory can be formed and built up as a result out of different ways of data collection. Diffusion of innovation theory can be built up by extending existing models or by creating new frameworks. Applying a survey and testing hypotheses, the research contains deductive elements as well. But the research was rather inductive, as new theory should evolve in the form of a framework by applying both qualitative and quantitative analyses based on human perceptions of diffusion of innovation barriers.

While the deductive elements of a survey focus on a large sample, the inductive elements rather focus on a small sample of subjects for qualitative evaluations. The following illustration demonstrates the applied mixed-methods strategy.



Source: Developed for research from Rudestam and Newton (2007)

Figure 3-1 – Adaptation of research wheel to mixed-methods research strategy

The adapted research wheel shows that an initial literature research was a starting point for formulating research questions, which was followed by exploratory case study research focusing on a specific situation but also by the exploratory analysis of survey data. The advantage lies in the flexibility of permitting changes during the course of the research regarding its emphasis (Saunders et al., 2007, pp. 120). The case study research can identify additional contributing barriers forming a proposition for a modification of the introduced theoretical LF-model.

Hypotheses, originating from qualitative research, are formed and researched by empirical data gathering as quantitative research approach confirming or not confirming the theoretical LF-model and its modification. The following two sections discuss the suitability of qualitative and quantitative methodology forming the mixed methods.

3.2.3 Suitability of a case study cross-site approach

Case study research can bring an understanding of a complex issue and can add strength to what is already known through previous research. This qualitative research method examines a real-life situation and according to Eisenhardt (1989) and Siggelkow (2007) can provide the basis for ideas and potential extensions of the introduced methods. Case study research has been questioned concerning its possibility of being representative but researchers should be "…optimistic that we can learn some important things from almost any case" (Stake, 2005, p. 451).

Yin defines the case study research method as an empirical inquiry that investigates a contemporary phenomenon within its 'real-life context' (Yin, 1984, p. 23). The author suggests techniques for conducting the research in different steps of designing the case along research questions, performing the case, evaluating and analysing the data and preparing the result (Yin, 1994).

Distinguishing between different types of case studies according to Yin (2003), a single case describes one unique case, whereas the generally preferred idea of multiple cases is that the findings of one case apply in the other as well. Another way of distinguishing case studies is whether it is holistic when researching an organization as whole or embedded by researching sub-units. (Saunders et al., 2007, p.140). The author regards the applied case study research approach as holistic.

Stake (2005) distinguishes two basic types of case studies. Apart from an intrinsic case study in which the focus is on the specifics of a case itself, a case study can be instrumental and multiple. This case study research is instrumental, as it plays a supporting role in identifying barriers for technologies, which redraws generalization.

The instrumental nature of the initial case study research was chosen to study one part of the data by conducting interviews within one topic by interviewing various stakeholder groups of similar interests. Therefore a cross-site analysis approach (Miles & Hubermann, 1994) was performed for different sites to achieve a certain synergy and to add value and importance to the results of the specific topic chosen by a qualitative application (Patton, 2002). Patton (2002) explains that it would be important to perform that kind of research without using a specific hypothesis.

Qualitative multi-site case study research from a small number of respondents can produce very useful outputs if information-rich data can be gathered for each site. Purposefully chosen samples of each site should be analysed following the rationale of the research. This is explained in section 3.3.4 following the suggestions of Patton:

“The validity, meaningfulness, and insights generated from qualitative inquiry have more to do with the information-richness of the cases selected and the observational/analytical capabilities of the researcher than with sample size.”

(Patton, 2002, p. 245)

The basics for having a cross-site approach concerning its principle and strategy are explained by Miles and Huberman (1994). They explain it as a “…theory that uses the diversity in front of us (…) fully to develop and test well-grounded set of explanations” (Miles & Huberman, 1994, p. 207) with the purpose of enhancing generalizability with cross-site analysis. With purposeful sampling and a good analysis, questions can be answered even beyond the specific case according to Miles and Huberman.

For a cross-site approach, Miles and Huberman (1994) suggest strategies for sampling and analysing. With a case-oriented and a variable-oriented strategy, they suggest two basic strategies for cross-site analysis. In contrast to a case-oriented strategy, the variable-oriented approach looks for common topics across the case sites. As different stakeholder groups were considered as sites, the strategy chosen is variable-oriented. Principles for analysing cross-site approaches are introduced in section 3.3.4.

The exploratory case study research is about the problems digital radio is facing compared to the classic FM technology concerning its diffusion since the beginning of the 21st century. As the diffusion of digital radio technology has not been taken place in Germany, the question is why digital radio with digital audio broadcasting (DAB) technology has not achieved a high diffusion rate in Germany (Töpfer,2008). Reasons for the failing of this innovative technology are subject of the research and can be combined with the theoretical LF-model. Data gathering was performed empirically by expert interviews. This investigation is to be seen as a German case study research with multiple sites or smaller cases. It is referred to as ‘case study research’.

It is a real, unique and interesting story about various organizations and the process of technology adoption, which suites well for a case study approach (Yin, 2003). The idea of a case study is also to give the story behind potential results in order to outline a project’s success (Neale et al., 2006). Therefore, the story is told since the introduction of digital radio in the German market with some background information given in section 4.1. The focus of the case study research was on details of the challenges and difficulties of the diffusion of digital radio in Germany. Based on the results, a survey approach was followed as illustrated and discussed in the following section.

3.2.4 Survey strategy and the use of an online questionnaire

A survey strategy very often is referred to as applying a designed questionnaire (Kervin, 1999; Saunders et al., 2007). The explanation of deVaus (2002) is broader and describes this approach as applying the same questions in the same order to each participant, which could be a structured interview as well as an online-questionnaire. Because respondents are asked the same questions, it is a powerful tool to collect answers for specific research questions and objectives (Saunders et al., 2007). Dillman's (2000) and Oppenheim's (1992) suggestions, how a questionnaire should be designed are widely applied, as this data collection method is very popular for survey strategies. Nevertheless, it is difficult to design a good questionnaire (Bell, 2005) and its details are explained in section 3.4.1.

Referring to the research objectives, the main advantage of a survey approach lies in a quantitative data gathering for analysing the existence of diffusion barriers and according perceptions by industry experts.

The survey research is analytical, as it was mainly performed for finding patterns and interrelations as well as confirming and generalizing findings of qualitative research. The examination and explanation can provide patterns regarding the types of industries and products. Barrier variation depending on additional aspects such as technology intensiveness or grade of regional economic development can also be illustrated (Wasserman & Shaklee, 1984; Saunders et al., 2007). A list of barriers can be put in an order of importance/relevance and illustrated e.g. by bar charts. The survey should give the possibility of ranking and clustering to give practitioners an idea of barrier existence. The target audience for the survey were therefore practitioners such as marketing and sales experts, who can evaluate barriers and diffusion aspects due to their experience and current job role in manufacturing high-tech companies.

According to different publications (e.g. Saunders et al., 2007), there are various types of questionnaires, which can be divided into self-administered and interview-administered questionnaires via different media. According to Churchill and Iacobucci (2010), questionnaires are classified by the methods used for administration (personal, via telephone, post, fax or email and online).

High costs and involved efforts excluded the possibility of personally approaching respondents considering the size and spatial distribution of a sample with a sufficiently high number of respondents required for generalization. Budget and time constraints made surveys via post or fax also impractical. Applying an online questionnaire gives a powerful possibility using this state-of-the-art media access and tools of our society. The benefits can be summed up as follows:

"During the past 10 years, online survey methods have produced the most revolutionary changes in survey research ever experienced. Technological developments in internet survey software have enabled personalised and dynamic surveys at a level of sophistication never before possible. In addition, campaign management software has emerged to accurately track, profile, and monitor respondent history and progress – all at a cost savings over previous methods."

(Smith et al., 2006, p. 132)

Despite their practical and cost advantages, online questionnaires also have disadvantages such as a low response rate (Saunders et al., 2007). Nevertheless, taking into account the benefits and considering the target audience, the applied survey of this research was designed as self-administrative online questionnaire. This gave the possibility of an easy survey administration and providing it to potential respondents all over the world (Wright, 2005). This seemed to be a suitable approach to follow the research objectives for empirical data gathering.

The questionnaire has a very wide and open focus regarding the different possible technologies of a number of industries and its global orientation. In contrast to that, the initial case study research has a relatively narrow focus with one technology in a small regional area. How the combination of these methods provides an integrated research approach is illustrated in the following section.

3.2.5 Research design integrating objectives and mixed methods

Before explaining, how the different methods are integrated into the research design, the pre-phase of literature review (chapter two) has to be mentioned as well. With critical reviews and appropriate sampling of primary, secondary and tertiary literature (Saunders et al., 2007, pp. 64) the goal was to investigate used models and findings from marketing experts for diffusion of innovation and its barriers. Recognising that gaps in current knowledge exist, the research objectives are explained more precisely within this section.

The research work is based on the expertise in technology marketing and constraints of the current decade, both applying qualitative and quantitative research methodologies. This mixed-methods research was structured in several phases incorporating several methods, phase one as an initial exploratory case study research, phase two as a generalizing survey approach and phase three to present the resulting pattern, as Figure 3-2 illustrates.

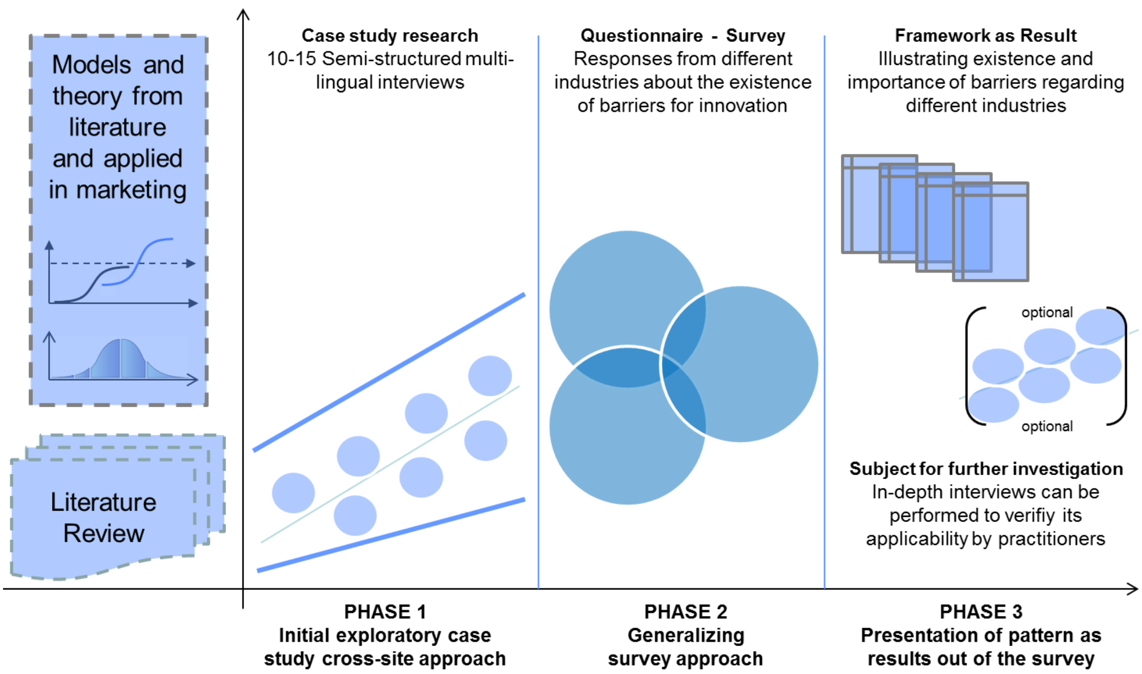


Figure 3-2 – Research design integrating applied methods

The first phase consisted of an initial exploratory multi-site case study research. Here semi-structured interviews with stakeholders along the value chain of digital radio for the German market were performed. The LF-model was tested concerning its usability and validity. It forms the basis for hypotheses of exploratory nature to be researched in phase two via quantitative research.

A survey was performed in phase two based on the barriers of the LF-model and barriers identified. The question is whether a generalization of the main result of the survey could be achieved. Additionally, variances and patterns of barriers were researched regarding different industries.

The illustration shows the order in which the qualitative and quantitative data was gathered, but a certain prioritization should be considered as well. The relative emphasis of the data out of the two data gathering approaches is unequal as a higher weight is given to the survey following the case study research results. According to the following table (Table 3-2), this study consists of three research objectives, which were followed during different phases, applying results from different methods.

Name	Description	Results from	Phase
Objective 1	To find out, which barriers do prevent innovation from its diffusion and if needed extend MacVaugh and Schiavone's (2010) results of investigation.	Literature review, Case study research, Online-questionnaire	Pre-phase, Phase 1, Phase 2
Objective 2	To identify a pattern relating barriers related to their applicability in different industries and different regions and potential interdependencies.	Online-questionnaire	Phase 2
Objective 3	To contribute to the performance of technology marketing by modifying or extending the LF-model from MacVaugh and Schiavone (2010) as framework for practitioners	Case study research, Online-questionnaire	Phase 3

Table 3-2 – Refinement of research objectives regarding chosen methodology

Based on the researches of the last decades and their outcomes an overview is given outlining barriers in a structured approach, following the first objective. To illustrate different barriers, the LF-model (MacVaugh & Schiavone, 2010) was used as reference. The applied LF-model might be extended by new results.

Questioning whether the identified barriers are equally important in different industries and economic regions guides to the second research objective. The results of the case study research in phase one and the survey in phase two help to verify the existence of barriers according to MacVaugh and Schiavone (2010) and the applicability of their LF-model. Variations can be identified for different economic regions, industries and types of products. Interdependencies between barriers may exist as well. The opinions and perceptions of experts from different industries (e.g. technology marketing, product management) as part of the survey help to identify patterns of diffusion barriers.

The mentioned respondents are practitioners, who may benefit from an applicable framework. The providing of such a framework is a third research objective and was mainly followed in phase three. With the results of the quantitative and qualitative research steps in phase one and two potential improvements to MacVaugh and Schiavone's (2010) LF-model were outlined. This should act as a strategic framework for decision-making and overcoming barriers of diffusion. One aim is to extend the awareness of barriers for strategic decision-making.

Optional data gathering may be performed as further research for evaluating the applicability of the developed framework in the according environments (not being part of this thesis). In-depth interviews can contribute qualitatively to the outcome of the framework presented.

While it seemed appropriate to use both, qualitative and quantitative research techniques, to achieve the outlined objectives; a deductive approach for testing hypotheses was followed in order to achieve the chance of generalization. Nevertheless, the deductive approach was of exploratory nature. Newly identified barriers, and various aspects, such as the interrelation of barriers and the similarity of different industries, led to the formulation of propositions. Based on the case study research results from phase two, hypotheses were identified and described in the next section in order to be applied for survey analysis.

3.2.6 Discussion of hypotheses refinement based on case study research

Having a look at the diverse results of the case study research and at the research objectives, explanations for the missing success of digital radio in Germany can be found by applying the LF-model. The case study research shows that some barriers are perceived as more important than others. Therefore, hypothesis H1 was refined to:

H1: There exists variation in the respondents' perceptions of influencing barriers limiting the diffusion of an innovation.

To research the hypothesis, a ranking of barriers can be performed based on the quantitative outcome of the survey. Furthermore, variation can be analysed by comparing contribution loads of reliability analysis to the complete model.

The variables of the LF-model were not observed directly. Therefore, the different barrier items of the model were operationalised to form the according barrier variables, as explained in section 3.4.2. Thus, a framework could be built and researched with and without additionally identified barriers in different approaches to gather the result related to this hypothesis.

A problem for non-adoption mentioned as result of the case study research was the anticipated availability of a better technology, when information is already accessible about a future technology. Under the expression 'leap-frogging', technology adoption might not occur because the launch of a new generation of an even better technology may be approaching. As this aspect is similar to the barrier item of a communities' orientation towards the older technology from the LF-model (see Table A-1), an additional barrier item served as alternative to research the model variable of *orientations*. The item describes that there is already an even better technology or being under discussion within a community of users. It was verified via H1 and the reliability analysis.

As another result of the case study research, the barrier of a ‘missing inter-industrial collaboration’ is an interesting aspect for modifying or extending the LF-model and was also researched via H1. The aspect contributes to the LF-model variable of *orientations*, as an entire industry might not be oriented towards a technology and would not cooperate to develop a market. Quantitative research brings up results, whether the identified barrier item contributes to the LF-model in its macro domain.

The case study research demonstrates the co-existence and interrelation of barriers. However, potential interrelations are researched for the LF-model only. The hypothesis of H2 with an emphasis on the LF-model was reworded focusing on perceptions:

H2: There exist correlations of different strengths among the respondents‘ perceptions of the barrier variables of the LF-model.

Although literature refers to adaptability, the case study results show that it was not a main barrier for the diffusion of digital radio. However, new generations, moving faster and changing their needs and interest, may require a certain level of adaptability. Therefore, new technologies provide a certain possibility of upgrades and modifications to comply with future needs. Whether a lack of adaptability should be considered as barrier is a research question worth following. Therefore, a variable of *adaptability* was operationalised by suitable statements regarding the perception of adaptability and a lack of adaptability for communities. Additionally, potential consequences for other industries were also considered. If a technology does not provide certain adaptability, it might not be used in applications of other industries (Döhl, 2006). Such challenges for the diffusion of new technologies were researched by the agreement of practitioners, as explained in section 3.4.2.

To investigate the importance of considering adaptability as a separate barrier variable H1 was applied, but the following refined version of hypothesis H3 was researched additionally.

H3: There exists a correlation between respondents' perceptions of the adaptability of a technology and respondents' perceptions of the technology's utility as barrier variables.

A weak dependency to a technology's *utility* as barrier variable can be evaluated by relating it to the respondent's perception of the importance of *adaptability* of an innovation. The barrier variables were formed by scales of barrier items whose perception supports the research via hypothesis H3. Their significance can additionally be researched and compared to other barriers items and variables via hypothesis H1.

Based on the case study research results, it seems that *environmental awareness* should not be considered as separate barrier variable. However green argumentation and perception has a separate influence on diffusion. Therefore, the following refined version of hypothesis H4 was used to be researched in addition to H1:

H4: There exists a correlation between respondents' perceptions of environmental friendliness and respondents' perceptions of barrier variables of the social structure.

A dependency of the *social context* to other LF-model variables can be evaluated by relating the respondent's perception of the importance of changes in the *environmental awareness* of society agreeing or disagreeing on suitable barrier statements for the diffusion of new technologies. Those statements relate to environmentally-friendly perception, access of sustainability information and greenwashing and are researched by the agreement of practitioners, as explained in section 3.4.2. Their significance can also be researched and compared to other barriers items and variables via hypothesis H1 in addition to hypothesis H4.

The formation of hypotheses originates from the conceptional development based on literature review. Additionally, refinements of the hypotheses were performed and discussed within this section regarding the results of qualitative research. The hypotheses were researched via a survey as quantitative research. How the survey and the case study research were approached regarding data gathering and the analysis of data is illustrated in the following section. For each methodological approach, its design, data handling, sampling strategy and validity and reliability aspects are presented.

3.3 Data collection and analysis techniques for the case study research

3.3.1 Design of expert interviews

Various publications (Stake, 1995; Patton, 2002; Neale et al., 2006) state different elements of a case study research approach. The biggest challenge is to understand the contextual meaning (Kvale, 1996), which for this case study research was digital radio in Germany. Interviews can achieve pure facts and the contextual meaning of the real world (Kvale, 1996; Kvale & Brinkmann, 2009). They also give the possibility of interacting to make sure that questions are understood correctly (Hannan, 2007). This gives the researcher the flexibility of restating and questioning meanings, which interviewees give to their behaviour according their values, beliefs and motives (Richardson et al., 1965; Hannan, 2007).

As the diffusion of digital radio has not been taken place, industry experts were approached to discuss, why the according technologies with DAB and DAB+ have not had a high diffusion rate in Germany. These expert interviews contribute to the plausibility and confidence of theoretical research by giving different ideas due to their professional angle of perspective. The concrete information and different points of view can also be used for further investigation (McNamara, 2009).

But there are also critics for the use of interviews for data gathering. There can be differences in asking stimulating questions from one interview to the next. Moreover, interviewees may try to impress the interviewer (Scheurich, 1995; Hannan, 2007). A challenge is preventing a bias situation because the interviewee might tend to please the interviewer and to strive for approval (Hannan, 2007) by tone or non-verbal behaviour, like facial expressions. In addition, interviewees may insist on having company with a colleague or to have a telephone or video conference instead of face-to-face.

The interviewer needs to be motivated to establish a positive objective environment to get a lot of information out of the interview (Hannan, 2007). Concerning potential criticism, there remains the possibility of allowing the reader to evaluate about possible influences. Therefore, the questions were documented (see Appendix C) and relevant answers are described with the results in section 4.1. Criticism regarding the interview technique can be faced with the additional data gathering via a survey in order to achieve plausibility and confidence.

According to Williamson (2006), among ethnographic data collection instruments the interview technique is mostly used with semi-structured questions. Wengraf (2001) and Woods (2006) explain that some pre-set questions allow more scope for open-ended answers. The type of interview to be semi-structured appeared to be the most suitable to explain the story behind the diffusion of digital radio in Germany.

For achieving the diversity of the topic including the main aspects of research, a script of the semi-structured interview was used for introducing the topic, the main discussion and closing the interview, as suggested by Woods (2006) and Myers (2009). The following table illustrates the different sections.

Nr	Section description	Objective
1	Nature of the project (objectives, ethics protocol, transcript)	Administrative
2	Introduction of Interviewee and role and experience	Knowledge
3	Introduction of topic around “digital radio”	Introduction
4	Diffusion of digital sound broadcasting	Focus of research
5	Additional value of digital sound broadcasting	Focus of research
6	Perception of digital sound broadcasting	Focus of research
7	Looking into the future of digital sound broadcasting	Focus of research
8	Barriers for the diffusion of a digital radio standard (including identification of most critical barrier for diffusion)	Main focus of research
9	Final remark, summary and explanation of data disclosure	Administrative

Table 3-3 – Sections of semi-structured interview about digital radio diffusion

The used interview script consists of nine different areas, whereas the first and last sections were of organizational nature (see Appendix C). After an explanation of the research itself and the interview objective, an explanation of ethical constraints was provided. Then the interviewees were asked to describe themselves and sketch the job responsibility and company background, before discussing the different sections as follows.

Along and within the sections, several reasons and argumentations can be found for constraints on the diffusion of digital radio in Germany. Each of the seven discussion sections contains a question which is very broad, giving room for a diversity of information. Apart from some ideas of potential questions for prompting into a direction if needed, the script contains a final key question at the end of each section. The questions necessary to collect all the data are described in the script as a key question. If the key question was answered already, this question was skipped. The questions and objectives for each section are provided in Appendix C.

The key questions of section eight are on barriers for diffusion. The interviewer asked for the main barriers for the diffusion of the digital radio standard in Germany. This section is the main focus influencing the research progress and subject to take into account when analysing the data and drawing conclusions. Finally, each semi-structured interview was closed with a summary of section eight about barriers for the diffusion of digital radio, before a final statement concerning data disclosure was made.

As the interviewees have very different technical and business experience, it may be possible that the interview provides additional information. If interviewees had relevant additional information for the case study research, it was taken into account as well.

Two pilot interviews were performed to confirm the applicability of the introduced structure and the design of the interview, as suggested by various literatures (Gordon, 1975; Williamson, 2006; Saunders et al., 2007). The pilot interviews did show that sometimes there is the need of asking for a final statement, in case the interviewee is still ready for giving further information. A smartphone turned out to be sufficient as recording device. Thus, semi-structured interviews were held after pilot testing, applying the interview script and applying techniques for taking notes.

3.3.2 Techniques for taking notes and transcription of interviews

To take notes during the interview besides the technologies for audio recording, several techniques can be used. The technique of mind mapping, which is based on hemisphere theory (Buzan, 2003, 2007), is suggested for business research students by Quinton and Smallbone (2006) and for taking notes in the business environment by Illumine (2010) and Landale (2011).

Applying the mind mapping technique for interviewing, pre-determined interview sections illustrated as main branches were used for possible responses that the interviewer has to write down (see Figure D-1). The mind map allowed an easy integration into the according branch as interview section at any time during the interview and during transcription analysis.

Although some interviewees might grant allowances for taking down notes (Hannan, 2007), the interviews were not halted to do so. In addition to mind mapping, the interviews were voice recorded (Saunders et al., 2007) by using smartphone functionality. The flexible and re-usable structure of mind maps allowed cross-linking of the information. For each interview, a mind map based on initial interview notes and transcription analysis was developed (see Figure D-2 and Figure D-3 as example). This served as the most practical approach.

Because of time constraints, it was decided to outsource the textual transcription to service providers. The transcribing organization signed a confidential agreement with the researcher. Knowing how the interviews were designed and transcribed and results are presented, it is important to have a clear strategy which samples are chosen, as introduced in the next section.

3.3.3 Sampling strategy

For case study research it is interesting studying multiple comparison groups (Glaser & Strauss, 1976). Miles and Hubermann explain that "…having multiple sites increases the scope of the study and, thereby, the degrees of freedom" (Miles & Hubermann, 1984, p. 151). For the case study research of digital radio, different sites all along the value chain were chosen.

Patton (2002) explains that the purpose of the study leads to the careful application of volume and specifics of information distinguishing between different types of purposeful sampling, which may vary depending on the need during the course of research. In contrast to probabilistic sampling, the "…logic and power of purposeful sampling lie in selecting information-rich cases for study in depth" (Patton, 2002, p. 230).

Listeners, as potential adopters of digital radio, were not considered as it is assumed that knowledgeable experts provide more insights on problems with the new technology, besides a high effort towards data gathering. Maximum variation sampling as a type of purposeful sampling (Millan & Schumacher, 1997) was applied because it is beneficial to have different aspects of all stakeholders along the value chain of digital radio. Common aspects across the industrial value chain regarding the two decades of introducing digital radio could be identified from different perspectives. A further perspective is provided by a group of interviewees which do not represent a specific value chain part but have a special knowledge. The mix of purposeful sampling aspects with the objective of having a maximum variation and with a case-oriented approach with reputational considerations, seemed to be the most suitable approach in order to achieve plausibility of information. Being listeners themselves, these experienced industry practitioners are regarded as proxies, capable of representing the adopters' opinion.

Considering the value chain of the industry for FM as analogue radio (the old technology) and DAB/DAB+ as digital radio (the new technology), it has to be pointed out that the industrial structure is similar. Content has to be gained first in studio and radio stations. The broadcasting infrastructure is needed for coding and distribution and equipment is used by listeners for radio reception. Additionally, radio and broadcasting experts are illustrated over the whole value chain. These four main value chain parts, considered as sites, are highlighted in blue frames by Figure 3-3, as follows:

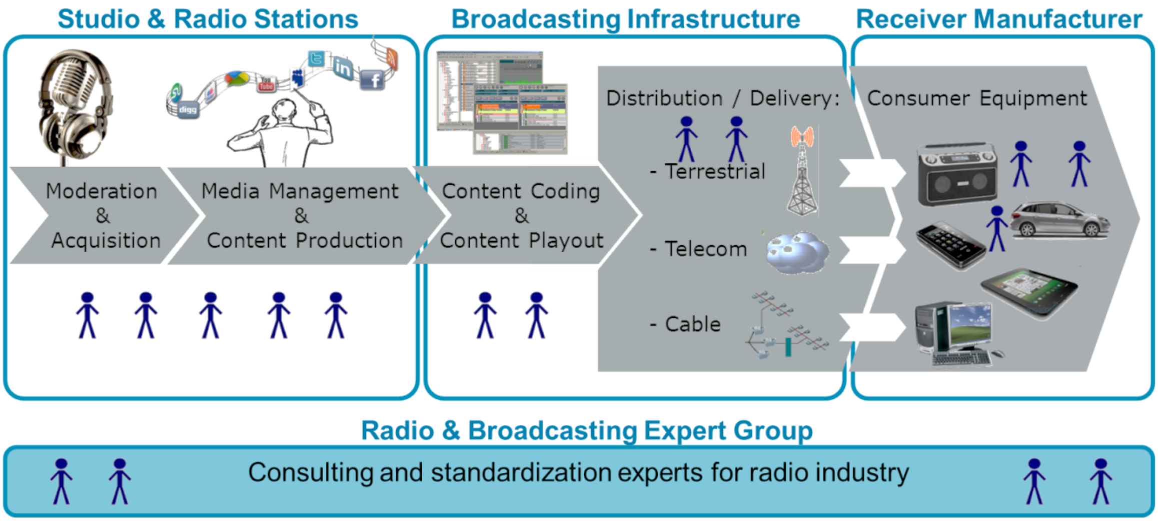


Figure 3-3 – Interviewees along the value chain for digital radio

The introduced parts of the value chain can also be subgrouped, illustrated by grey arrows. As the subgroups of interviewees are not that big and for the reason of time constraints it seemed to be sufficient to have one or two representatives interviewed. Taking the different distribution and reception possibilities (terrestrial, via satellite, via internet) into account, only the technology of DAB/DAB+ via the terrestrial medium ‘air’ was considered. The listeners as end-users were not considered to be interviewed.

For plausibility reasons and case type dependant, knowledgeable experienced consultants, standardization and industry experts can bring additional perspectives. In contrast to companies of different parts of the value chain, they represent a perspective on the whole value chain, illustrated by the blue box at the bottom of Figure 3-3.

It has to be mentioned that interview partners may be very careful with information, as they may perceive the topic as relatively political. It was emphasized that the research is purely academic and no data would be gathered for political reasons and usage.

With the applied sampling strategy, interviews with very different interviewees were held. With the taken notes, the recorded files and resulting transcriptions, huge data is available. How data analysis is managed and which techniques were used is explained and illustrated as part of the next section.

3.3.4 Data analysis methods

3.3.4.1 Introduction and discussion of analysis approach via meta-matrices

After collecting and transcribing the data from multiple sites, its meta-information was analysed via an approach for matching patterns (Miles & Hubermann, 1994; Yin, 1994). The analysis via a meta-matrix (Miles & Hubermann, 1984) requires the relevant entities, through which data can be examined. The interviewees represented entities related to the value chain for digital radio. The analysis approach is described for purely textual analysis by Diesner and Carley (2005), like a transcript, and according to Miles and Huberman (1994) it is applicable for analysing interviews as well.

The structures used were several meta-matrices, in which different information of interviewees is incorporated and additionally the different themes, which are reasons and constraints why digital radio technology has had difficulties in its diffusion within the German market.

According to Miles and Huberman (1984), several types of meta-matrices would help for a cross-site analysis (Miles & Huberman, 1984, p. 151). Cross-site methods "… can actually be used in the study of several individual people, each seen as a small 'case' " (Miles & Huberman, 1984, p. 151). Therefore each individual interview partner can be taken into account for the different analysis approaches with meta-matrices according to Miles and Huberman (1984). Referring to the sampling strategy, a site was considered as a group of stakeholders (illustrated by blue frames in Figure 3-3). The following table gives an overview of the different sites.

Site of the value chain	Subgroups of stakeholders	Type of purposeful sampling
Studio & radio station	Moderation & Acquisition	Maximum-variation
	Media management & content production	Maximum-variation
Broadcasting infrastructure	Content coding & content playout	Maximum-variation
	Distribution / Delivery (only equipment for the terrestrial signal DAB)	Maximum-variation
Receiver manufacturer	Stakeholders for consumer equipment (only receivers for the terrestrial signal DAB)	Maximum-variation
Radio & broadcasting expert group	Consultants and standardization experts as stakeholders for the whole value chain	Case-oriented

Table 3-4 – Sites with subgroups for cross-site analysis of the case study research

The analysis was performed via several matrices based on an unordered meta-matrix (Miles & Huberman, 1984). The goal was to bring together basic information concerning the success of digital radio from several sites of the value chain. This approach seemed to be sufficient, as it is not too complex and its nature is rather on a descriptive emphasis to include all relevant data.

As initially, a lot of information is processed using one table, this chart is called 'monster-dog' by Miles and Huberman (1984, p. 152). It can be used for further gradual refinement, summarization and reduction by partitioning and clustering in order to identify contrasts between sets of sites on different variables. How relevant data is excerpted from the initially big ‘monster-dog’ matrix is shown in the following illustration.

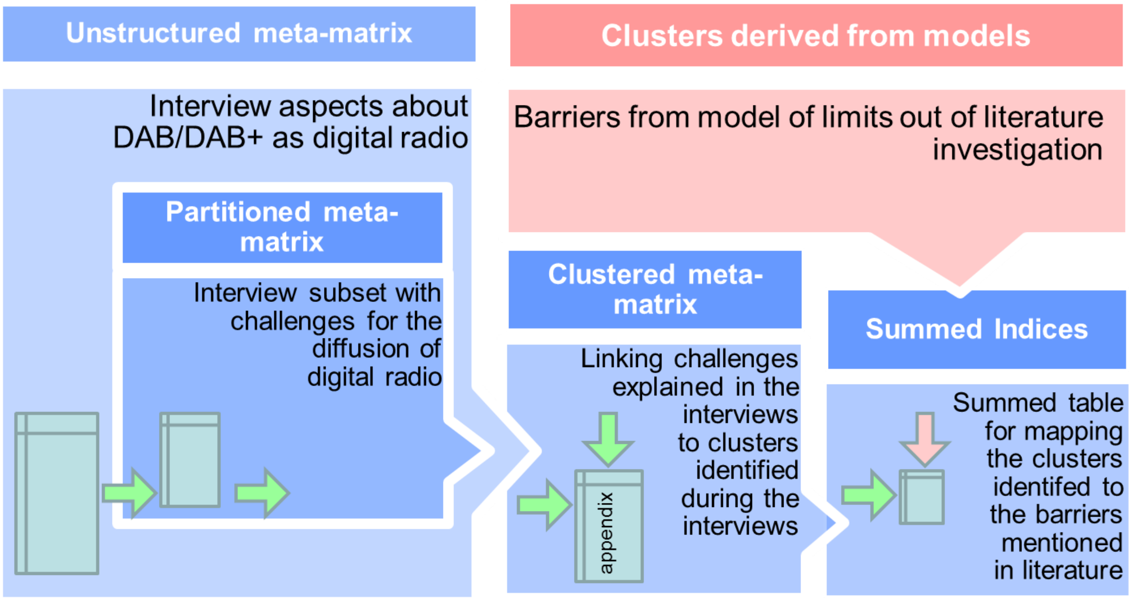


Figure 3-4 – Analysis approach via meta-matrices

Figure 3-4 shows the usage of four different tables (see illustrations in Appendix I for meta-matrix dimensions). The data gathered in interviews is represented in an unstructured meta-matrix, which was used as a subset in a second meta-matrix. With the help of cross-category clustering, a third matrix was created which was subject of simplification and used for a mapping table to refer to the LF-model. The formation and use of the different tables is explained and illustrated in the following section.

3.3.4.2 Formation and use of an unstructured, partitioned and clustered meta-matrix

The initial matrix was used for summarizing all relevant data from the interviews as an initial step. This was followed by steps of identifying a suitable subset and clustering the data, which was subject for later refinements according to Miles and Huberman (1984). The initial unordered meta-matrix turned out to be very large, because information from all four sites was incorporated, as the table in the appendix shows.

Another matrix was used for identifying the relevant data as refinement or summarized version of the original unstructured meta-matrix (Miles & Huberman, 1984) related to difficulties of the diffusion of digital radio. This is a subset of the initial unordered meta-matrix and is very large as well.

Based on both, the initial unordered meta-matrix and its subset, a third table as most important table was created by identifying clusters across different sites and different interviewed stakeholders and contains analytical categories. Its creation was performed by using the subset and analysing the different interview information of each site for barriers and problematic diffusion challenges described for digital radio. At the same time, it was double-checked with the 'monster-dog' that no contradicting information was used.

Explaining an example of a more significant analysis (12 different sites each with about three interviewees), Miles and Huberman suggest a decision rule of at least two and ideally three sites sharing the same information to be identified as being connected via a cluster (Miles & Huberman, 1984, p. 156). For this research, the rule of identifying a cluster was applied with two sites sharing an identified barrier or a related problem for the diffusion of digital radio. Clusters were identified before they are regrouped to a smaller number of crucial diffusion challenges. Short summaries and some important quotes were incorporated as illustrations. The clustered meta-matrix contains quite important information (Miles & Huberman, 1984) and is included in the appendix.

So far, the introduced clusters would contain crucial challenges and barriers for the diffusion of digital radio as innovation in Germany. Mapping those clusters to barriers of the LF-model would help non-specialists outside the specific broadcasting industry to understand which general barriers exist and which occur for digital radio. The following section discusses the form of mapping.

3.3.4.3 Discussion of the form and use of a summed index for mapping

According to Bryman and Burgess (1994), mapping and interpretation of qualitative data is an important step especially for developing frameworks, when "…all the data have been sifted and charted according to core themes" (Bryman & Burgess, 1994, p. 186). A similar approach is used by Groth (2010) with visual aids to map clusters of theoretical challenges of learning environments and results checked against empirical data. The mapping was performed with empirical data against theoretical data, as the key objectives of the qualitative approach with an initial case study research is to identify aspects of existing concepts and typologies with the LF-model.

According to Bryman and Burgess (1994), there are different mapping techniques for analysing relationships of different patterns and concepts (e.g. Seidel, 1998; Austrian, 2000). Martin and Sunley (2003) point out that there is "…no agreed method for identifying and mapping clusters" (Martin and Sunley, 2003, p. 19). Considering different methods existing in literature may exceed the approach of this cluster analysis. Therefore, simple mapping tables were developed, but the basic principle is still the same:

> *"Whichever route is followed, the basic processes are the same: the analyst reviews the charts and research notes; compares and contrasts the perceptions, accounts, or experiences; searches for patterns and connections and seeks explanations for these internally within the data".*
>
> (Bryman & Burgess, 1994, p. 186)

Therefore, the connections identified as mapping the clusters, representing the phenomena of digital radio, to the barriers from literature were underlined by explanations within the data. As information from literature exists concerning different barriers for diffusion of innovation, two mapping tables were used for mapping summarized clusters (Miles & Huberman, 1984) to barrier variables and barrier items from the LF-model (MacVaugh & Schiavone, 2010). They give indications which barrier variables, items and domains of LF-model are referred to. The tables are comparable to summed indices for a descriptive matrix (Miles & Huberman, 1984, pp. 158).

The matrices were filled with checkmarks for mapping the meta-matrix clusters to the barriers from the LF-model. A cell with a '+' shows a strong positive confirmation of a barrier from the LF-model for the diffusion of digital radio, whereas a '-' indicates a negation of the barrier from the LF-model. A weak positive confirmation is illustrated by '/+'. In case a cluster contributes or refers to a barrier from the LF-model but neither has a positive nor a negative confirmation, the tendency is shown with '+/-' but the reference is provided.

To be able to map the generated clusters additionally to the different domains of the LF-model, a third dimension had to be taken into account, as the following visualization illustrates for barrier variables. The third dimension is incorporated by using the letters indicating the domains of the individual ('I'), a community of users ('C') and the whole market or industry ('M').

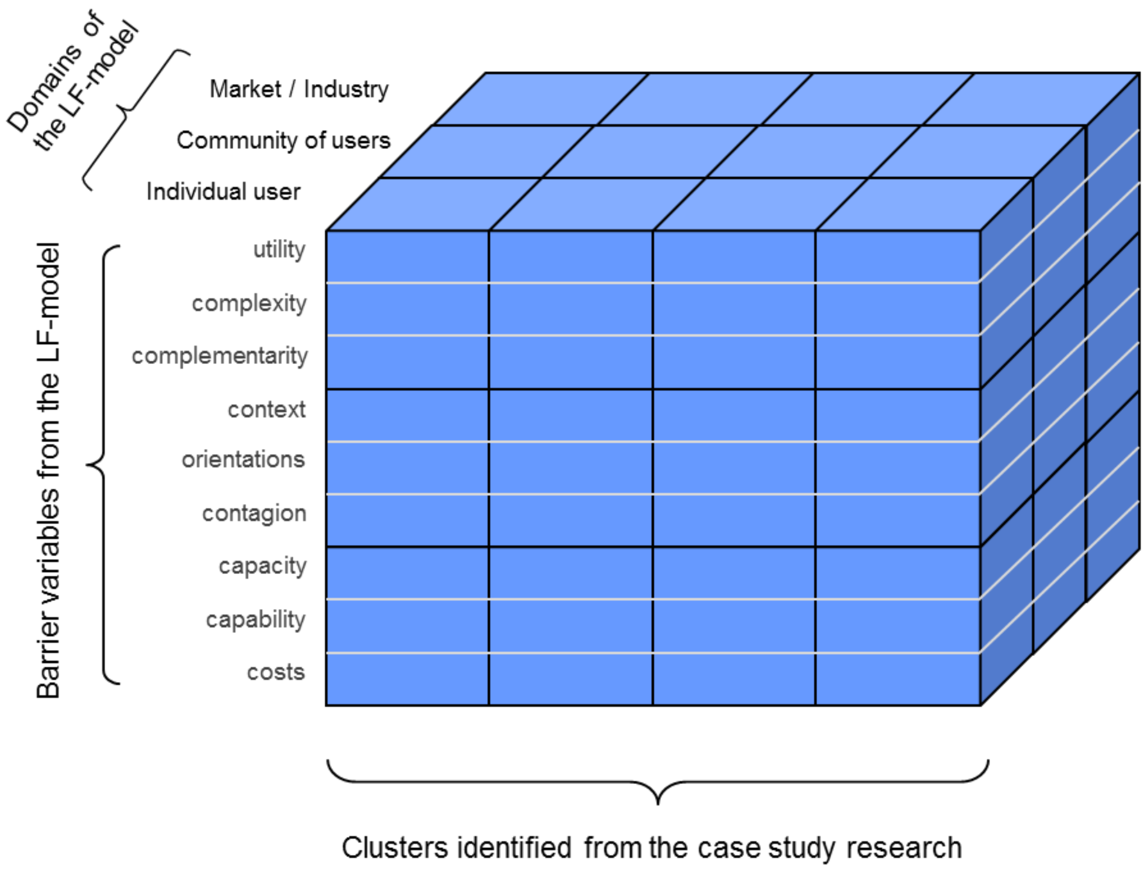


Figure 3-5 – Mapping of clusters to two dimensions of the LF-model

If a barrier from LF-model literature (a row) has no checkmark, it is not discussed in the interviews; the according cells are left empty. If a column of a barrier cluster has no checkmark, it is not in the LF-model and can be subject for its extension.

According to literature (Smith & Robbins, 1982; Miles & Huberman, 1984) there are different possibilities to move from the initial unordered meta-matrix to alternate ordered views with evolving meta-matrices. It is important to apply "…a matrix display that best captures the dimensions the researcher is interested in and that gets all the pertinent data arranged in readily analysable form" (Miles & Huberman, 1984, p. 159). Because the variations among the different sites are of minor importance due to the goal of identifying barrier information, a different way of arranging information was chosen by the summed indices as mapping tables for barrier variables and underlying items. In addition to the summed indices, another table is provided for the barrier items with an adapted wording.

Having explained how the analysis was performed, there is the need of discussing the tables, filled with data out of interviews. How the interviews were held and which procedures were used to take notes down, is discussed in the next section.

3.3.5 Procedure and execution of interviews

Within a certain period of time the status of digital radio diffusion might change slightly regarding the deployment of the needed network. Therefore, the goal was to achieve all interviews within a very short period in time of few months in 2012. The interviews were held and analysed from April to September 2012, depending on the availability of the interviewees. As soon as respondents confirmed to participate in the research, time and location were agreed on.

The semi-structured interviews were held to elaborate or clarify the understanding of digital radio technology and to gather information on barriers, discussing the past, the current and the future status of digital radio and potential facilitators for a successful diffusion. The setting for the interviews for qualitative research differed due to the preferences of interview partners. Mostly, respondents were given the description of the case study research and an ethical explanation some days in advance and asked to review and comment the topic before conducting the interview.

Due to the nature of semi-structured interviews, an interview script as rough guideline of questions was used and respondents were told so. In some interviews additional questions were asked for clarification and understanding. During and after the completion of the questions from the script, additional topics were discussed, to which the respondent gave further insights. Some of these topics did deepen and expand the information discussed. In some interviews additional questions were raised to prompt topics if they had not come up. Other interviews were more conversational.

After the interviews, the researcher used the notes written down and completed mind maps as summaries to capture major elements of the interviews and prepare a structure for adding more information after the transcription.

The telephone and face-to-face conversations, which took on average about 20 minutes, were audio-recorded with permission of the interviewees in line with ethical considerations and transcribed afterwards. The interview recordings were transcribed into text by cooperating with suitable transcription services. The results from the interviews were sent to the interviewees for checking according to ethical agreements.

Interview notes already provide an idea of the existence of various barriers with the case study research about digital radio and can already be seen as convincing in terms of its potential for usable findings for the co-existence of barriers and their interrelation. Nevertheless, after completion of the interviews for all sites of the value chain, the transcriptions were analysed and thematic elements were used to feed the prepared mind map (see Appendix D) and to fill a matrix for analysis.

As next step, the interviews were summarized and integrated in the described unordered and clustered meta-matrix (Miles & Huberman, 1984) that allows a variable-oriented analysis and gives an overview of the variety in different aspects for the success of digital radio. The cells of the matrices listed aspects or quotes from each respondent. Comments or quotations were analysed and grouped by certain elements as discussed in section 3.3.4. The statements of the four different sites along the value chain seemed to be similar in the one or other aspect but not all aspects mentioned are the same for each site.

Respondents to the interviews of each site as a group of stakeholders along the value chain of digital radio in Germany shared many impressions and experiences made during the introduction of the digital radio standards in Germany. The technique of semi-structured interviews allowed them to recall and critically review their personal experiences in rich detail. This allowed a good understanding of problems, obstacles, constraints and barriers for the introduction of the standards into the German market.

The cross-site analysis provided the possibility to understand the importance of the shared information and experiences. For presenting the results, the developed meta-matrices are presented in the following section. The final overview of the results is given by the mapping of clusters against the barriers from the LF-model. A conclusion is drawn by applying empiric data of the case study research to explain the result.

3.3.6 Reliability and validity aspects of case study research

Whereas in quantitative research, the quality can be verified by accuracy, relevance, and reliability of quantitative measurement, qualitative research follows the goal of understanding and explaining the observed phenomena. To understand the observed phenomena, the researcher him-/herself is the instrument (Patton, 1990).

For case studies the quality of findings depends on the credibility of the researcher, his or her ability (Patton, 1990) and the researcher´s rigour and effort (McMillan & Schumacher, 1997). Golafshani (2003) therefore suggests treating the quality of qualitative research as follows:

“Although reliability and validity are treated separately in quantitative studies, these terms are not viewed separately in qualitative research. Instead, terminology that encompasses both, such as credibility, transferability, and trustworthiness is used”.

(Golafshani, 2003, p. 600)

The interviewer needs to be eager to collect information although there might be constraints on resources and the availability of respondents, as the suggestion of Patton (1990) to perform “…best with your full intellect to fairly represent the data and communicate what the data reveal given the proposed study” (Patton, 1990, p. 372) describes. According to Patton (1990), the interviewing researcher is an instrument contributing to qualitative research.

Triangulation was strived for to achieve assurance that validity is achieved not only from the point of view of the reviewer but also from the point of view of others, to whom the results can be transferred to. Triangulation was accomplished via a multi-site case study research approach with several sources of information (more than a dozen interviews). Consistency was identified between those sources by only considering strong communalities of information. Semi-structured interviews with persons being very familiar with the topic guaranteed rich information from a variety of stakeholders (Woods, 2006). Literature, publications and news articles are additional sources for information and contribute to triangulation.

Interviews require a good and healthy conversation to allow information exchange (Patton, 1990). Therefore, the environment for the interview was chosen to be ideally at the interviewees’ location for their convenience. During data analysis the researcher consciously evaluated the strength and clarity of findings during the interview to judge their credibility and trustworthiness. The six month of collecting, discussing, analysing and structuring data out of qualitative research represented an important period for drawing conclusions. During this time, the focus was put only on this data gathering approach.

Due to McMillan and Schumacher (1997), it is difficult to evaluate reliability in qualitative research, which is why they focus on disciplined subjectivity. Under disciplined subjectivity it can be understood that a researcher monitors and evaluates own activities during all research phases. To reduce research bias, McMillan and Schumacher (1997) propose various strategies, of which some were considered to reduce research subjectivity. The dates, places and persons of the interview were logged in a suitable format. Ethical considerations and actions were recorded and formal confirmation activities with interview partners were performed. The audibility is guaranteed by digital and semi-automatic data recording and transcription technologies as suggested by McMillan and Schumacher (1997). For categorization and analysis, meta-matrices were used.

Different measures were taken to achieve a high quality of this qualitative data gathering approach. A more objective observation of reliability and validity aspects is possible for quantitative research methods such as a questionnaire, applied as second research method. Its quality assessment as well as its design aspects and sampling strategies are introduced in the following section.

3.4 Data collection and analysis techniques for survey research

3.4.1 Constraints & challenges with deciding for an online questionnaire

Applying an online questionnaire, there has to be the decision on the tools to choose for designing, administering and analysing the questionnaire. A website is a good possibility of advertising the questionnaire and inviting to access it via different media (Saunders et al., 2007). The academic environment of the research provided a professional account with Qualtrics[1] for designing and administrating an online questionnaire via a website. As the tool satisfies all requirements needed, this software was used for the online questionnaire.

Concerning the size of the survey, a sufficient number of responses should be achieved because the likely response rate for this kind of survey might not exceed 1-2% (Saunders et al., 2007). However, the confidence of a person responding this type of questionnaire is usually very high (Saunders et al., 2007, p. 358). Despite their practical and cost advantages, online questionnaires have the disadvantage of low rates of questionnaire returns. Therefore, the design of the questionnaire was essential and additional effort is needed to be put into a high user-friendliness to allow the completion of the online form as easy as possible, e.g. with closed questions ideally being of interest to the respondents.

Due to Witmer et al. (1999) the chosen type of questionnaire also allows to manage it online and remember potential participants to complete the questionnaire via messages. In addition, incentives can be given for every response received to increase the response rate (Deutskens et al., 2004; Birmholtz et al., 2004; Wright, 2005; Göritz, 2006). A donation to a charity organization, such as UNICEF[2] was considered.

Among several advantages (Wright, 2005), the chosen kind of questionnaire had the big advantage of analysing the collected data by computing. For analysing the results,

[1] The product service of Qualtrics can be used as part of an academic agreement with Plymouth University. (http://www.qualtrics.com)
[2] UNICEF is one of most known international charity organizations worldwide and are active worldwide (http://www.unicef.org/)

several statistical techniques and tools exist (Saunders et al., 2007) but analysis by the software of SPSS® Statistics[3] from IBM® has become state-of-the-art and thus, was used. It provides several analysis methods required for this research and referred to as part of the next section.

Besides tools for administrating and analysing the questionnaire, constraints exist regarding the target group. The ideal target group of the online questionnaire consists of experts in marketing and sales of technology with job roles in product management, sales, marketing, business development or general management. As it takes a high effort to reach end-users as potential adopters and their individual view might be limited, it is assumed that the mentioned target group represents both the micro-level view of potential adopters and macro-level views. For example, the role of a product manager is defined as owning the interface to "…the buying public" (Luck, 1969, p. 33). Nowadays, a good way of approaching experts is via professional social networks and their big success in recent years (Boyd & Ellison, 2007; Li, 2008; Prince, 2008). This seemed to be a good contemporary choice to gather suitable and reliable data from professionals on an international level. Social networks have gained much importance in information access (Kaplan & Haenlein, 2010; Kim et al., 2011) also for professional networking (Skeels & Grudin, 2009; Papacharissi, 2009, Chapple, 2012). As this allows accessing different groups of interest more easily online, suitable existing platforms such as LinkedIn and according social groups were used.

Two approaches can be followed using social networks. An internet-mediated online questionnaire can be distributed via a link in direct messages to experts and can be published in forums of expert groups in social online networks (Chapple, 2012).

Given the substantial time constraints faced by the target group and the distribution method via social media platforms, a good design was regarded as being very important for the success of the questionnaire.

[3] The abbreviation of SPSS® stands for "Statistical Product and Service Solutions" and is the most established statistics software used in research. (http://www.ibm.com/spss)

3.4.2 Design of the questionnaire

3.4.2.1 Operationalization of barriers by statements as Likert-scaled items

Before explaining the structure and the design of the questionnaire with its core element of the challenges for innovative technologies, this section focuses on the operationalization of barrier items and barrier variables. Their evaluation is performed via statements describing the barrier items. These measurement instruments were observed Likert-type items representing barrier items. Subsequently, barrier variables were formed as non-observed Likert scales. The statements and constructs are introduced within this section.

From the LF-model several expressions were extracted as barriers for innovation following the reading guideline of the model (MacVaugh & Schiavone, 2010). Looking at Table 2-3, the first barrier in the first row falls under the conditions for technology and contributes to the *utility* level of influence (barrier variable) being present in the domain of individuals and community. According to the authors of the LF-model, it has to be read as ‘New technology fails to replace older technology when (…) utility (…) is perceived to be less than the older technology’. These statements were used in the questionnaire to ask respondents for their level of agreement regarding the challenge of a new technology based on their experience (see page four of Figure F-5). In contrast to barrier items from the LF-model, the barrier variables cannot be observed directly. According to the LF-model, barrier items as statements add to different constructs of barrier variables.

The used variable names in the course of this thesis have a letter as prefix, describing the condition of technology (‘T’), social structure (‘S’) and learning (‘L’), before a short form of the variable follows after an underscore character. These variable names are used for barrier variables. The names for barrier items have the same composition and an additional extension after an underscore character indicating the domain of the model (see section 3.3.4.3). If a barrier item covers two domains, two letters are used.

The first conditional area of the LF-model describes technology conditions by the variables *utility* (T_Utlty), *complexity* (T_Cmplx) and *complementarity* (T_Cmplm). Additionally, with *adaptability* (T_Adptb), a fourth variable was introduced as part of the thesis. The second area describes social structure conditions. The related variables are *social context* (S_Cntxt), *orientations* (S_Orntn) and *contagion* (S_Cntgn). Furthermore, with *environmental awareness* (S_EnvAw), a fourth variable was introduced. Learning conditions form a third area with the variables of *learning capacity* (L_Cpcty), *learning capability* (L_Cpblt) and the *costs of learning* (L_CstLrn).

As potential extensions of the LF-model, two additional barrier variables and additional barrier items were tested, as described in section 3.2.6. For the additional construct of *adaptability*, according statements that can fit into the LF-model structure were operationalised. Similarly, statements as measurement instruments were also used for the additional construct of *environmental awareness*, as the following table shows.

Item name	Statement applied in survey	According construct of barrier variable
T_Adptb_I	It (the new technology) is not adaptable and is not perceived to be future-ready. Changes/upgrades are difficult.	Adaptability
T_Adptb_C	The new technology cannot be adapted to specific needs (e.g. local needs) of a community.	Adaptability
T_Adptb_M	It (the new technology) is for a specific application/market and cannot be adapted for usage in other markets or industries.	Adaptability
S_Orntn_C2	There is already an even better technology (not available yet) under discussion within a community of users.	Orientations (alternative item)
S_Orntn_I	Industries, which are related to the new technology, are not cooperating to develop the market.	Orientations (additional item)
S_EnvAw_I	The perception of the new technology is not environmentally-friendly.	Environmental awareness
S_EnvAw_C	Aspects of sustainability are not published and explained in detail for the product innovation.	Environmental awareness
S_EnvAw_M	Marketing is exaggerating when stating that it is environmentally friendly (e.g. by 'green' branding).	Environmental awareness

Table 3-5 – Additional barrier item statements to construct barrier variables

Additional items for Orientations were introduced for testing potential modification to the LF-model. The statement of ‘missing inter-industrial collaboration’ (S_Orntn_M) originated as clear result from the case study research and may extend the LF-model. With the statement of ‘…are towards an even newer technology under discussion’ (S_Orntn_C2) an alternative to the statement ‘…are towards the older technology’ (S_Orntn_C1) was tested.

The opinion of the respondents concerning the importance of a barrier item was asked for by Likert-type items (Likert, 1932; Clason & Dormody, 1994). Consequently, the newly introduced statements and statements originating from the LF-model, referred to as barrier items, were operationalised as Likert-type items due to their characteristics as directly observable element for statistical data gathering. The constructs of new and LF-model variables, referred to as barrier variables, were operationalised as Likert-type scales due to their characteristics as indirectly observable element for statistical data gathering.

The following table gives an overview of barrier items, the according statements and their names allocated to the construct of the barrier variable they contribute to. An additional table (see Table E-1) describes the construction of barrier variables and model indices (MacVaugh & Schiavone, 2010). The latter may be subject of further research. Newly introduced barrier items and variables (not being represented in the LF-model) are marked. A scheme of the suggested modifications of the LF-model with according barrier variables is shown with Figure 5-1. During the course of this study the statement texts are presented in reduced versions.

Barrier variable	Barrier item	Barrier statement
Utility (T_Utlty)	T_Utlty_IC	The utility (benefit) of the new technology is perceived to be less than the older technology.
	T_Utlty_M	The new technology fails to exceed the older technology's measurable specifications.
Complexity (T_Cmplx)	T_Cmplx_IC	The technological complexity makes it difficult to perceive new features. (The focus is rather on its overall effectiveness.)
	T_Cmplx_M	Radically new technology with a high level of complexity needs a lot of effort and therefore cannot be introduced frequently.
Complementarity (T_Cmplm)	T_Cmplm_IC	The complementarity of an older technology results in higher total utility. (e.g. existing standards and infrastructure)
	T_Cmplm_M	It does not lead to dominant design within an industry because an older technology retains a strong position in the market.
Adaptability (T_Adptb)	T_Adptb_I	It is not adaptable and is not perceived to be future-ready. Changes/upgrades are difficult.
	T_Adptb_C	The new technology cannot be adapted to specific needs (e.g. local needs) of a community.
	T_Adptb_M	It is for one specific application and cannot be adapted to be used in other markets or industries.
Social context (S_Cntxt)	S_Cntxt_I	Individuals face difficulties in accessing the new technology and related material (e.g. due to poor infrastructure).
	S_Cntxt_C	Corporate divisions or other communities restrict its access to only a few selected individuals (e.g. depending on their role, responsibility or their performance).
	S_Cntxt_M	Access is restricted by external institutions (e.g. government).
Orientations (S_Orntn)	S_Orntn_I	Personal orientations towards its use are negative.
	S_Orntn_C1	The community of users favours the older technology.
	S_Orntn_C2	There is already an even better technology (not available yet) under discussion within a community of users.
	S_Orntn_M	Industries, which are related to the new technology, are not cooperating to develop the market.
Contagion (S_Cntgn)	S_Cntgn_IC	The word-of-mouth or contagion effect is not strong enough to displace existing user community norms.
	S_Cntgn_M	Poor execution of marketing prevents positive word-of-mouth effect or contagion.
Environmental Awareness (S_EnvAw)	S_EnvAw_I	It is not perceived as being more environmentally friendly than the older technology.
	S_EnvAw_C	Sustainability aspects of the new technology are not published or are not explained to the community of users.
	S_EnvAw_M	Marketing is exaggerating when stating that it is environmentally friendly (e.g. by 'green' branding).
Learning capacity (L_Cpcty)	L_Cpcty_I	Individual learning capacity or ability to learn the new technology is limited.
	L_Cpcty_C	There is not enough resource in the organization or user community to access training.
	L_Cpcty_M	The technology producers are not providing sufficient resources and guidance for users to learn how to use it.
Learning capability (L_Cpblt)	L_Cpblt_I	The way of using it is very different compared to the older technology.
	L_Cpblt_C	No expert groups have been created for the new technology.
	L_Cpblt_M	Possibilities for experiencing or getting familiar with the new technology are limited within the industry.
Costs of learning (L_CstLrn)	L_CstLrn_IC	There are high switching costs and learning efforts for individuals and organizations with the new technology.
	L_CstLrn_M	The efforts needed for learning how to use the new technology within the industry are very expensive.

Table 3-6 – List of barrier items and the constructs of barrier variables

According to Dillman (2000) the information from the evaluation of the barrier item statements on a Likert-type scale is considered as opinion variables. Often, seven-point scales are used because of their capability to achieve high reliabilities of the constructed scale variables (Finn, 1972; Ramsay, 1973; Nunnally, 1978; Cox, 1980; Cicchetti et al., 1985; Preston & Colman, 2010). It is suggested to use such scales as it could easily be collapsed afterwards, if appropriate (Symonds, 1924; Likert, 1932, Dawes, 2008). Scales with more points would rather not be used because they are not increasing the reliability and for some extent there are also limits in processing the information by respondents (Miller, 1956). Referring to cited literature of the analysis performed by MacVaugh and Schiavone (2010), perception and attitudes towards the adoption of a technology were also asked for in surveys applying a seven-point Likert scale (Morris & Venkatesh, 2000).

Each barrier item therefore was placed on a seven-point scale in form of the presented statements, ranging from one (strongly agree) to seven (strongly disagree) according to Likert (1932). The respondents were asked to indicate their level of agreement with the statements in relation to it as possible reason for the non-adoption of a new technology based on their experience by clicking the appropriate scale for the Likert-type item. The responses reflect the importance and existence of the barriers and were used as observed variables.

All literature given by MacVaugh and Schiavone (2010) were reviewed for identifying valid scales and instruments for designing the online questionnaire. Besides the size of the scale some literature shows a similarity in terms of modelling and analysis barriers and according variables. Stating the barrier that a community can be towards the older technology, MacVaugh and Schiavone refer to Moore and Benbasat (1991). They also used scales to operationalize influence factors, whereas the number of statements used is between four and nine. Generalizations and differences are explained based on the analysis of the barrier item individually as well as their Likert-scale construct referred to as barrier variables.

Similar to their research and to existing schematics of the theory of diffusion of information systems as a diffusion variance model (Cooper & Ymud, 1990; Crum et al., 1996; Agarwal & Prasad, 1998; Wade et al., 2005), a scheme is used as basis for researching the importance of different factors represented by barrier variables for the diffusion of a technology. The following diagram (Figure 3-6) illustrates the different factors influencing the diffusion of an innovation and representing different subordinate barrier items.

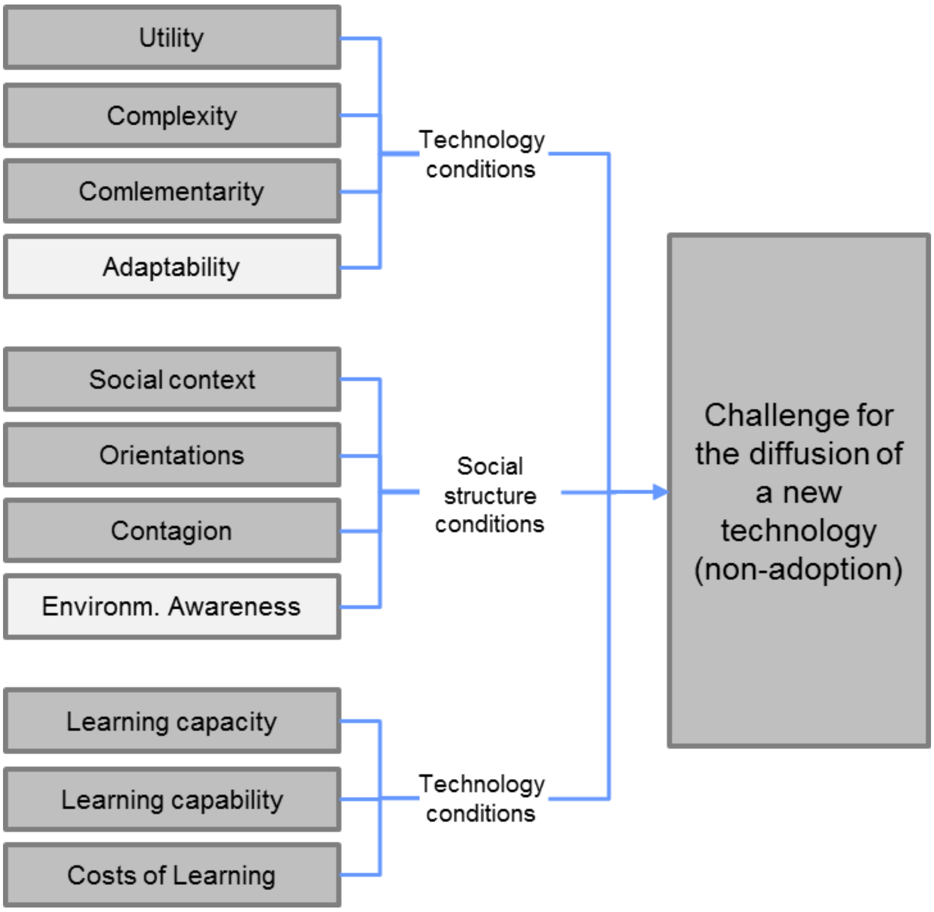


Figure 3-6 – Model schematics of barrier variables as factors for diffusion

The sketch represents barrier variables influencing the non-adoption of a new technology. The unobserved barrier variables, which were calculated by its subordinate observed barrier items as measured indicators, are depicted graphically with rectangular forms.

3.4.2.2 Demographical data and attributes for clustering

As part of the quantitative data gathering, demographical data was asked for in the questionnaire, such as participants' age group, their country of residence and their level of education. Additional data about their profession and job environment, such as their position, years of experience in their position and the company size of their employer, was asked for to have a possibility of assessing the quality of the answer and potential filtering (See Appendix F).

For clustering, additional information about industry, product type and economic region is required. The latter was derived from the country information according to the statistics division of the UN (2013) and to according definitions of emerging countries as part of a Goldman Sachs study of N-11 nations (Wilson & Stupnytska, 2007). The question on country of residence was re-used from the Qualtrics question library of 'State-Region-Country'. Information about industry was also used to classify whether the industry, the respondent is working in, is manufacturing high-technology or medium-high-technology according to Eurostat (2009; 2011) and OECD (2013, p.240). This is described as degree of technology intensity of the industry. For describing the type of product, they are mainly working with, additional data is needed. Therefore, questions were applied about the length of the product´s life cycle, the nature of its type of innovation (Christensen, 1997) and whether it is considered as industrial or consumer good.

The product type, the economic region and the industry information are mainly used for pattern analysis. The variables are considered as attribute variables according to Dillman (2000) and Saunders et al. (2007). The type of this data is descriptive and has to be treated as nominal data (Saunders et al., 2007; Zikmund et al., 2013).

The demographical data and the attributes are used as descriptive elements for statistical data gathering as part of the survey. The following table (Table 3-7) gives an overview of the variables and their names.

Variable	Name	Description
Age	Age	Age group of respondent
Country of residence	Country	Country of current residence
Economic region	EcoRegion	Variable deviated from country to distinguish developed countries, emerging countries and developing countries
Education level	Edu	Level of education (distinguishing between different achieved graduations)
Job Position	JobPos	Current job position (targeting product management, sales, marketing, business development, general management)
Job experience	JobExp	Years of experience in current job (distinguishing different time periods)
Company size	CompSize	Number of worldwide employees of current employer
Industry	IndRe	Industrial segment the respondents works in (different industries such as automotive, chemicals, consumer electronics, electric/electronic manufacturing, IT, medical equipment, oil and energy, pharmaceuticals & biotech, telecommunications)
Technology intensity of industry	IndHT	Different levels of technology intensity as industry classification (distinguishing between high-tech, medium high-tech, low-tech and medium low-tech industries)
Product type	Good	Type of good the product can be categorized (either industrial good as B2B or consumer good as B2C)
Product life	ProdLife	Typical length of a product life in the industry of the respondent (distinguishing different time intervals)
Types of innovation	InnoDis	Frequency of working with discontinuous innovation (categories of timely frequencies: always-never)
	InnoRev	Frequency of working with sustaining (revolutionary) innovation (categories of timely frequencies: always-never)
	InnoEvo	Frequency of working with sustaining (evolutionary) innovation (categories of timely frequencies: always-never)

Table 3-7 – List of demographic and attribute variables used in the survey

The presented variables were mostly observed for statistical data gathering and analysis as part of the survey. The variables of an industry's technology intensity and economic regions were not observed but were deviated from observed variables.

The introduced variables, observed in the survey, were used to fill a data requirements table (see Table E-2). To have an overview of the coding of both observed and deviated variables a coding table was used additionally. How the variables were asked for in the online questionnaire is presented in the next section.

3.4.2.3 Development and design of the questionnaire elements

The questionnaire was designed by outlining the different data variables presented in the previous section with the help of a data requirements table, a code book and coding instructions (see Table E-2, Table E-3 and Figure E-1 from Appendix E), as by Litwin (1995). The investigative questions and used variables, categorized in opinion, behaviour and attribute, are outlined in a data requirements table (Saunders et al., 2007, p. 368). This assured that data from the questionnaire would contribute to the research questions and objectives. The types of closed questions are indicated with the data requirements table. List, category and rating questions are used, because those types of closed questions (Foddy, 1994) can emphasis pattern research more effectively.

At the beginning of the research instrument, an introductory text was presented to the respondents and at the end of the survey acknowledgement was given for their participation. As there were quite a number of questions to be answered, a challenge was that respondents completed the questionnaire. Therefore, the attention of the respondents needs to be won explaining the motivation and context in a small cover letter (Dillman, 2000; Saunders et al., 2007). Therefore, its design contained the introduction of the researcher, the research title, the academic environment including a logo; its objective, incentive information and the approximate duration of the questionnaire (see Figure F-2 from Appendix F). This allowed potential respondents to perceive credibility and give weight to the research project.

With a selection of very different questions, the breakdown of the survey was designed with consideration. Using Qualtrics software, blocks of different questions were applied, as the following table (Table 3-8) shows. All question pages of the different blocks followed the cover letter in a similar design (see also Appendix F).

Block	Content	Description
1	Introduction	Introductory page for motivating the respondent to complete the questionnaire
2	Job-related questions	job position, job experience and company size
3	Industry- and product-related questions	Industry type, product type (length of product life-cycle)
4	Technology-related questions	Type of good (industrial or consumer good) and type of innovation
5	Diffusion challenges	Statements to be evaluated on a Likert-type scale of agreement levels
6	Person-related questions	Country of residence, age and level education
7	Closing	Final page for closing the questionnaire and saving the data

Table 3-8 – Question blocks of online questionnaire

At the beginning relatively important but moderately difficult questions were asked. At the end some personal questions were asked. The core block of the survey represented technology diffusion related challenges. Each question in block five asked for the evaluation of three to four statements before the next question continued with the evaluation of the next statement. The sequence of statements was not thematically grouped but listed randomly. Figure F-6 shows an example of the core part of the survey representing statements of technology-related challenges, which had to be evaluated by participants concerning their level of agreement.

A progress bar was used to allow assessing which percentage of questions is answered already. To have a high responsiveness of the survey, an incentive is given as discussed in section 3.4.1 in form of a donation to UNICEF for every usable set of response. Concerning its value, five US dollar seemed to be appropriate (Birmholtz et al., 2004) and the donation was confirmed at the closing page of the questionnaire.

Among the questions as part of demographics and the questions about innovation and diffusion challenges, one question might be simpler than others. To check the survey duration, its readability and a good comprehension of the questions, several tests were performed to receive feedback on the design of the questionnaire.

3.4.3 Pre-testing and Pilot testing

After the design of the questionnaire, it was reviewed and pre and pilot testing were performed. The purpose of the pilot test mainly is to make sure that the questionnaire is set up properly and there is the possibility of assessing validity and reliability (Saunders et al., 2007). In contrast to pre-testing, pilot-testing requires participants of the target population (Saunders et al., 2007). Thus, feedback on needed time, instructions, layout, questions (unclear, ambiguous or uneasy to answer) and additional comments were incorporated into the design of the questionnaire as Bell (2005) suggests.

After testing on a paper-based approach with an academic expert group of four business lecturers a pre-test among fellow research students and friends was performed using the online questionnaire tool in order to receive feedback concerning its length and instructions and to prepare for a pilot test. The feedback was the basis for modifying the questionnaire for a pilot-test.

After the pre-test, the pilot-test was performed with members of the actual target group of the main survey. Colleagues and friends in roles of marketing, business development, sales and project and product management were asked to participate in the pilot-test and giving feedback concerning the content. For pilot testing, the planned sample size of a dozen respondents all working in the needed job roles was exceeded. The pilot-test was answered by 20 respondents and feedback was received.

The main changes to the design based on the feedback of pre-testing and pilot-testing were made concerning the numbering of the questions, the progress bar, textual reduction in the instructions and statements. The number of questions was not dramatically reduced, but repetitive statement texts were reduced (e.g. reduction of ‘new technology’ to ‘it’). The sample for the pilot-test was mainly non-native English speakers and no problems were reported on understanding questions and instructions. Thus, it was assumed that the instruction and questions were clear enough. How knowledgeable experts are approached is explained in the next section.

3.4.4 Sampling strategy

The targeted experienced practitioners who work with technology-intensive industries are difficult to reach. When applying an online questionnaire and distributing it via information-rich social networks to a hard-to-reach sample (Philips, 2011; Baltar & Brunet, 2012), advantages and disadvantages need to be considered regarding its sampling approach. Among several social networks, LinkedIn represents a worldwide professional network (Skeels & Grudin, 2009, Papacharissi, 2009; Chapple, 2012) with more than 300 million members (LinkedIn, 2014). It was therefore chosen to stretch out to hard-to-reach experts, to benefit from an extended geographical scope and to increase the sample size (Baltar & Brunet, 2012). Response rates in social networks are higher than usual snowball techniques because of the available personal information of the researcher's profile and their participation in interest groups (Baltar & Brunet, 2012).

In spite of their popularity (Prince, 2008; Li, 2008), social networks have disadvantages regarding sampling (Baltar & Brunet, 2012; Abdesslem et al., 2012). The origin of the social media site of LinkedIn may be the reason of overrepresenting users of a regional area, language or other socioeconomic subgroups (Kwon & Wen, 2010; Phillips, 2011). Using the researchers account, a random sampling is not possible. Sampling bias may occur because members of the social network may be connected with the researcher and may be the same discussion groups (Gjoka et al., 2010; Phillips, 2011). The users of social networks may also show a pro-innovation bias in comparison to non-users. A further type of bias a self-selection bias, "…because people who feel strongly about a subject are more likely to respond" (Zikmund et al., 2013, p.190). Another critical aspect on using social networks is rather a moral one considering public discussions about usage of private data by the social network platforms (Krasnova et al., 2009). Reaching out via LinkedIn as professional network, sampling is performed knowing its limitations with biases but also benefitting from its reach.

A suitable sampling strategy needs to be followed (Saunders et al., 2007) to assure the participation of knowledgeable participants from high-technology industries. Approaching knowledgeable industry-experts by community sampling (Baltar & Brunet, 2012) via the LinkedIn network can be performed in alternate ways. One possibility is directly approaching people who are members of according industry groups and hold positions in marketing and sales of technology, while another is by publishing the survey in suitable expert discussion (Chapple, 2012). The latter is also referred to as self-selected sampling (Saunders et al., 2007; Zikmund et al., 2013). This sampling approach was regarded as suitable to contact industry experts all over the world, especially because of the constraints of a small budget and a tight schedule.

Discussions about marketing and sales of technology as well as about innovation were used as platforms to publish the questionnaire with an explaining text and an according link. They were identified in groups of product management, B2B marketing and sales, technology sales, technology marketing and business development. As the return rate was moderate at the beginning, sampling by directly contacting knowledgeable experts was preferred. Directly contacting knowledgeable industry experts via their membership of discussion groups within LinkedIn required a careful and purposeful selection of suitable respondents according to their job position and industry. Assuming their knowledge is shown by their participation in related industry discussion groups and a given job position in their profile, potential participants could be selected and contacted. The following social discussion groups with a big population and with topics of high-technology and medium high-technology industries were regarded as suitable:

- 'Automotive Management Professionals'
- 'Aviation & Aerospace Professionals'
- 'Chemicals Industry – sales and marketing'
- 'Consumer Electronics'
- 'Information Technology'
- 'Medical Devices Group'
- 'Professionals in the Pharmaceutical and Biotech Industry'
- 'Product managers Consumer Electronics'
- 'Telecommunications Professionals Network'

In addition, the groups of ‘Oil and Gas People’, ‘Linked:Energy (Energy industry expertise)’ and ‘The Logistics & Supply Chain Networking Group’ were considered.

Those groups represent large populations within LinkedIn, which represent industries with high technology intensity according to Eurostat (2011). The members of the groups were contacted in case their career description showed a position in business development or marketing, sales or product management. As LinkedIn has its origin in the US (United States) and many members are likely to have their origin there (Phillips, 2011), suitable criteria were used to reach out for group members representing emerging countries. As the different groups are relatively large with tens of thousands of members and for the reason of time constraints, several hundred representatives per group seemed to be sufficient.

With the described sampling strategy, perceptions about the existence and importance of barriers for the introduction of a new technology and the diffusion of innovation can be researched regarding different industries and economic regions. This sampling was additionally supported by the questions for data gathering according to section 3.4.2.2, which allowed a filtering of the response sets e.g. for job positions or economic regions.

It could be criticised that this choice of sample in professional social networks might limit the applicability of generalising conclusions. Therefore, demographic data such as education or job experience of the LinkedIn population filtered for the job positions and industries referred to in this section are compared with the sample. If the frequencies are comparable the sample seems to be representative concerning the sub-population within the social network of LinkedIn (see also section 3.4.7.2). It is hypothesised that a large proportion of experienced persons are members of professional social networks especially in high-tech industries.

As LinkedIn is regarded as an established social network for professionals (Skeels & Grudin, 2009; Papachrissi, 2009), sampling was performed purposefully and measures were taken to filter for the target group, this approach can be regarded as valuable data gathering. Nevertheless, the constraints need to be kept in mind during the interpretation of the analysed results. How the analysis of the data was performed is explained in the following section.

3.4.5 Data analysis methods

3.4.5.1 Handling of rank data and analysis by non-parametric techniques

Barrier items were operationalised as Likert (-type) items and barrier variables as Likert (-type) scales. In various publications (Jamieson, 2004; Carifio & Perla, 2007; Norman, 2010; Brown, 2011), discussions are described, how Likert scales have to be treated. Questions are for example, whether Likert scales can also be seen as interval data and whether the intervals between the values can be seen as equidistant or not. Most likely, the debates originate from the difference of Likert items and scales (Brown, 2011).

For a Likert-type item the intervals between the different values can barely be seen as equidistant (Goldstein & Hersen, 1984, p. 52). It is regarded as very difficult to calculate an average between different feelings e.g. on a scale with different agreement levels (Kuzon et al., 1996; Cohen et al., 2000; Jamieson, 2004). The intensity of the feelings between ‘strongly agree’ and ‘agree’ cannot be assumed to be the same as for other adjacent levels of the scale.

On the other hand, as Likert scales are calculated using various Likert items, the scales would result to be more gradual. Therefore, Likert scales are often assumed to be interval data (Blaikie, 2003). Carifio and Perla (2007) explain that analysis should be performed on the scale and not on an item and data could be treated as interval data. It should be noted that statistical analysis methods, such as descriptives, differ for ordinal and interval variables (Clegg, 1998). Nevertheless, referring to the discussion and publications illustrated, several publications explain that Likert response formats should be treated as ordinal data (Coombs, 1960; Kuzon et al., 1996; Cohen et al., 2000;

Jakobsson, 2004; Jamieson, 2004). Other publications take it further and even perform the analysis on Likert-type items (Clason & Dormody, 1994).

The barrier items of the survey were analysed as Likert items (the barrier items) but also as Likert scales (barrier variables), computed with the Likert-type items. This was performed by calculating the average of the corresponding items. The calculation of the Likert scales as part of this study varied in the number of subordinate barrier items (two or three items). Therefore, some barrier variables consist of more intervals and some of less. Consequently, all Likert scales of this research were treated as ordinal data. For ordinal data, parametric analysis methods and tests do not apply (Clegg, 1998; Kothari, 2004; Field, 2005; Saunders et al., 2007). Kuzon et al. go further and call it one of the "deadly sins of statistical analysis" (Kuzon et al., 1996, p. 265). Suitable analysis methods as non-parametric techniques are described in the next sections in order to achieve the research objectives.

3.4.5.2 Assessment of reliability and internal consistency of the LF-model with changes

To assess internal consistency of the set of barrier items, analysis of Cronbach's α (Cronbach, 1951; Mitchell, 1996; Field, 2005) was performed. With α-values of more than 0.7, reliability was assessed to be sufficiently high (Cronbach, 1951; Nunnally, 1978; Field, 2005).

As there are barrier items as statements deduced from the LF-model and both additional and alternative barrier items, introduced in section 3.4.2, an approach was to assess the potential modifications to the LF-model via Cronbach's α for reliability. However, the reliability of a single item as a potential extension to the LF-model should not be researched (Gliem & Gliem, 2003). The authors explain that single items may lack reliability and should not be used to draw conclusions. Therefore Cronbach's reliability tests were not performed on single items but with all statements that originate from the LF-model. Additionally, tests were performed in a differential approach to verify reliability contributions of further barrier items by the following modified forms:

- Barrier items originating from the LF-model with the alternative barrier item for the barrier variable of *orientations* (S_Orntn_C2 instead of S_Orntn_C1)
- All items originating from the LF-model plus the additional barrier item for the barrier variable of *orientations* (S_Orntn_M) as result of the case study research
- All items originating from the LF-model plus the items for the additional barrier variable of *adaptability* (T_Adptb)
- All items originating from the LF-model plus the items for the additional barrier variable of *environmental awareness* (S_EnvAw)

The resulting α-values were then compared. In case the α-value was less than the α-value of the original LF-model, the suggested modification was withdrawn. In case the α-value resulted to be higher than the value for the items originating from the LF-model, the modification was considered for further analysis.

Gulliksen (1950) comments that a higher reliability can be achieved by a longer test. Having many Likert-type items would therefore result in high values for Cronbach´s α. Similarly, a subset of barrier items were tested describing the conditions of technology, social structure and learning, introduced with Figure 3-6.

Apart from the reliability assessment of the complete model, the same evaluation can be performed for the model variables. According to Gliem and Gliem (2003), the quality with internal consistency can be assessed for every scale variable. Nevertheless, the reliability analysis was performed on the complete set as subjects for its model contribution and on three conditions, as the barrier variables were only constituted by two or three barrier items.

While this section describes the reliability assessment of the sets of barrier items that may form the model concerning their contribution to reliability, the next section describes how the barrier items themselves could be accessed regarding their central tendency of agreement.

3.4.5.3 Test of central tendencies and descriptives for demographics

Following the research objectives in an exploratory approach, initial data mining can be performed by illustrating demographic information from the questionnaire data, (Field, 2005; Saunders et al., 2007) in addition to frequency and contingency tables of agreements with barriers. To illustrate distributions of age, region, industries, visual instruments such as bar charts, histograms, pie charts and percentage component bars were used.

As initial tests, descriptive statistics were also applied for the ordinal data of barrier items and barrier variables. For a central tendency of the ordinal ranked data, the most frequent response was used, known as the mode (Field, 2005; Saunders et al., 2007; Zikmund et al., 2013). Additionally, the median value could give a further orientation. The mean value may be used for comparison. The results could be presented in a very easy way illustrating which barrier items are perceived to be more important than others comparing its levels of agreement by applying the mode and median value. Values, smaller than the central value (4.0), were considered as agreement. Values, larger than the central value, were considered as a certain disagreement. While this can be performed very well for Likert-type items, Likert-type scales would rather require the analysis with the median values (Field, 2005; Saunders et al., 2007), as the variables were calculated by various items and therefore the mode as the answer given the most would not apply as such. The comparison was performed with median values that are smaller or equal to 3.5 for agreement and bigger or equal to 4.5 for disagreement.

In addition, the skewness with values from -1 to +1 could be evaluated regarding the distribution of values and questioning whether the distribution is approximately normal distributed as further assessment. If the skewness value is clearly positive, this indicates there are too many low scores in the distribution to be normally distributed; negative values show a majority in high scores (Field, 2005).

According to Robbins and Heiberger (2011), it is useful to additionally plot Likert scales to present data in addition to central tendencies. Diverging stacked bar charts provide an effective way to communicate summaries of Likert-type data (Heiberger & Robbins, 2013). Consequently, using seven-point scales, the distribution of the seven responses for each barrier item as percentages of agreed and disagreed evaluation can be displayed centred at the neutral agreement position of the diverging stacked bar chart.

A similar approach for illustration was applied for the more gradually scaled barrier variables. The percentages for any agreement (values smaller or equal to 3.5) and any disagreement (values bigger or equal to 4.5) were summed up. The result was a three point scale, used for illustration only.

Central tendencies of both, barrier items and barrier variables were analysed via the barrier statements, respondents had evaluated. Suitable analysis methods for the identification of patterns were applied for both. To do so, tests for differences and variations were applied.

3.4.5.4 Tests of differences and variation

When analysing ordinal data for the test of significant differences, non-parametric tests apply (Townsend & Ashby, 1984; Clegg, 1998), such as Spearman´s Rho or the Mann-Whitney U-test (Gregoire & Driver, 1987). According to Whitley and Ball (2002) and Kothari (2004), non-parametric tests have the advantage that they are easy to use. According to Kothari (2004), they are less sharp than parametric tests and use rankings. Non-parametric tests do not suppose consequential assumptions which can not be met for this study, such as the homogeneity of variations when differences are researched (Whitley & Ball, 2002; Kothari, 2004). Because of this constraint, treating ordinal data and the exploratory nature of this research and the research objectives, the use of simple techniques seemed to be sufficient. The following paragraphs introduce suitable non-parametric techniques.

To test whether the distributions of two groups are different regarding its normal distribution, Kolmogorov-Smirnov is suggested (Kuzon et al., 1996; Kanji, 1999; Field, 2005; Saunders et al., 2007).

According to Field (2005), with systematic and unsystematic variations there are two different types. As part of the research, systematic variations were researched by evaluating the responses under different conditions, such as different regional areas. The according groups showing different conditions should have a sufficient size.

A popular non-parametric approach for analysing variances in ordinal data is the Mann-Whitney test for comparing two independent groups (Kuzon et al., 1996; Whitney & Ball, 2002; Field, 2005). Additionally, the Kruskall-Wallis test was used as non-parametric test to test more than two independent groups for variations (Kuzon et al., 1996; Field, 2005).

Following the research objectives in an exploratory approach, it is equally important to not only focus on the analysis test but at the same time present the according data (Saunders et al., 2007). Describing ordinal data (like the barrier items) can be performed by using frequencies and percentages in the responses per group (Blaikie, 2003), as presented in the previous section.

Tests for differences and variations were performed both for barrier items and barrier variables. For those barrier items originating from the LF-model, an approach for testing the structure of the LF-model can be followed by factor analysis.

3.4.5.5 Approach for factor analysis

The LF-model variables are referred to as limiting factors by its authors. Based on the composition of a model, dimension and variable reduction are often performed by applying exploratory factor analysis. The techniques are used to identify the construct and underlying factors of a set of measured indicators (Field, 2005). Similarly, principal component analysis is used to identify the number of latent factors and explore the possible underlying factor structure (Field, 2005; Child, 2006). With the set of measurable barrier items, such tests were performed as well. Applying a scree plot allows the identification of the number of underlying factors (Cattell, 1966). Referring to the LF-model, three factors would be expected referring to either the number of conditional areas or domains. Referring to barrier variables, nine factors may also be possible.

Assuming that there is no underlying structure existing, an initial approach for a principal component analysis was followed to verify whether a similar structuring would result as the one of the theoretical LF-model.

An attempt of a principal component analysis was performed with the statements that originate from the theoretical LF-model. Since the items may correlate, oblique rotation was chosen, according to Field (2005) in order to identify common themes among items with high loads (Field, 2005).

With the preliminary results of a scree plot (see Figure G-1), according to Cattell (1966) the number of factors of an underlying structure was four. Principal component analyses based on an Eigenvalue of 1 and based on fixed numbers of factors with three, four and nine factors were performed with maximum iterations of 50, with and without oblim rotation. Besides contributing to several components, some barrier items did show higher loads within an extracted component than others. Focusing on the highest loads, very fragmented themes could be identified (see Table G-1 to Table G-4). Nevertheless, they did not show a sufficient similarity to the structure of the LF-model of MacVaugh and Schiavone (2010) as a basis for designing a complete readable framework of potential barriers for practitioners as one of the research objectives. Therefore the possibility of applying factor or principal component analysis was not followed within this research.

Principal component or factor analysis may be performed in detail by others as further area of research. In the publication of MacVaugh and Schiavone (2010) suggestions for areas of further research are given, such as the evaluation of the relationship between the barrier variables of the LF-model. For those relations as well as for testing additional hypotheses as part of this research, different analysis methods were applied to test correlations and their strengths.

3.4.5.6 Tests for correlation

According to Saunders et al. (2007), there are two kinds of association, which are correlation and cause-and-effect relationship. In a correlation it is not clear, which variable is causing the change of the other whereas dependant variables are changed by another variable, known as cause-and-effect relationship. The correlation coefficient (coefficient r) represents a value between -1 for perfect negative and +1 for perfect positive correlation. If the coefficient is zero, the variables are independent.

For the correlation coefficient of two ordinal, ranked data variables, literature suggests using Spearman’s rank correlation coefficient known as rho (Field, 2005; Saunders et al., 2007) or Kendall’s rank correlation coefficient known as Kendall’s tau (Goodman & Kruskal, 1979; Saunders et al., 2007). According to Kothari (2004) both methods are suggested due to their advantages as non-parametric methods for ordinal data. According to the author, an assumption of a normal-distribution does not need to be met. Another advantage is their simple nature (Clegg, 1998). According to Saunders et al. (2007), Spearman's rho (Spearman`s ρ) for Likert-scales is often used in business studies, to which this investigation belongs to. However, according to the authors this assumes equally distributed distances between scale points such as ‘strongly agree’ and ‘agree’. If it is difficult to justify that the distances are the same between the different scales, Kendall's tau (Kendall`s τ) is preferred. Therefore, this non-parametric technique is used to measure the degree of correspondence between two rankings and assess the significance of it (Saunders et al., 2007, p.451).

According to Field (2005) Kendall´s τ is more accurate for smaller samples. As there are two different versions, the version of tau b is considered for squared tables, analysing the association of variables with a common scales and tau c for associations of different scales and different calculations. According to Field (2005) the usage of Spearman´s ρ needs to consider whether dichotomous variables are used and whether the hypothesis is of one- or two-tailed nature. As barrier variables are not dichotomous, Spearman's ρ was applied for the correlation of barrier variables. However, both non-parametric methods bring similar results (Kothari, 2004).

White and Korotayev (2004) suggest for non-parametric tests of ordinal data such as Spearman's ρ or Kendall's τ different expressions for strengths, which are from 'very strong' (>0.7), 'strong' (0.7 - 0.5), 'medium' (0.5 - 0.3), 'weak' / 'quite strong' (0.3 - 0.2), 'very weak' (0.2 - 0.1) to 'extremely weak' (<0.1).

According to Field (2005, p. 14), "…most research questions can be broken down into a proposed cause". For evaluating the correlation between an ordinal ranked data variable as the barrier items and an independent variable, different coefficients are discussed in literature, but most suggested methods require the same type for the two variables (e.g. assessing a dependent ordinal and an independent ordinal variable).

The independent variables used as part of this research are the type of good, the economic region and the type of industry to be tested with ordinal data of barrier items and barrier variables. Economic region can be regarded as ordinal as it provides three different levels of economic development. The variable for technology-intensity describes the extent of intensity of technology use as industry classification and it could be regarded as ordinal as it provides four levels of extent. However, correlation tests were not performed as it would be beyond the scope of this thesis. Variation among medium high- and high-tech industries followed the research questions. The tests with economic regions were performed with Spearman's ρ. The dichotomous variable of type of good was not tested on correlation with the barrier variables but on its variation.

However, in order to apply the different analysis methods, data needed to be gathered, pre-analysed, filtered and re-coded. How the survey was performed and how data was managed, the executed steps to bring up results are sketched in the next section.

3.4.6 Administering, managing and performing the online questionnaire

The questionnaire was prepared and tested from September to December 2012 within the academic environment of the researcher. A pilot test was performed with representatives of the target group. For administering the questionnaire, the online SW application of Qualtrics was used with some important settings and functions. It was prohibited that respondents can participate several times. For the most important questions, the respondent was forced to response and the questionnaire could not be continued without answering that specific question. With the online SW application of Qualtrics the participation could also be tracked over time. Preliminary demographic information could be accessed during the execution of the survey.

After its launch on January 5th 2013, the online questionnaire was active for about five months until June, 12th 2013. As described in section 3.4.4, LinkedIn was used for data gathering. LinkedIn members of discussion groups were approached by either a personal message or starting a discussion about diffusion of innovation barriers in the related group. Out of the 2291 participants only 1374 participants completed the survey until the last question. The online SW tool examined the completion rate as being about 60%. According to the tool, most respondents finished in less than twelve minutes.

The responses were checked for plausibility via several logical criteria to achieve a higher reliability. Responses were deleted, if the given age did not match the experience in the current job with a critical difference of 20 years. Other criteria of not considering results were regarding their completion. As the research topic is on diffusion of innovation, the value and quality of the answers depends on the experience with regarding technology. If the frequency of dealing with evolutionary, revolutionary or disruptive innovation was evaluated as ‘rarely’ or ‘never’ for all the three categories, the response was also not considered. After elimination of the answers regarding plausibility instructions (see Figure E-1), 1280 responses remained to be useful.

The data needed to be recoded concerning the industry because a comment field did permit to enter the industrial field in case none of the selectable options was suitable. This resulted in the industry variable of IndRe. With the recoded industries, the variable of IndHT was calculated regarding the technology intensity resulting in the four groups of high-technology, medium high-technology, medium low-technology and low-technology manufacturing industries according to Eurostat (2011). Non-manufacturing industries built a fifth group.

Additional variables were also calculated based on the country of origin. According to the United Nations categorization for geographical subregions and geographical regions (UN, 2013) the coding was performed. Additionally, the information of country and subregion was used to create the variable EcoRegion, representing the three different economic regions of developed, emerging and developing countries according to Wilson and Stupnytska (2007) and UN (2013).

Based on the recoding, additional filtering needed to be performed following the research objectives. As the focus is on high-tech industries with manufactured goods from developed and emerging countries, some responses needed to remain unconsidered. Responses from software industries were not considered. Neither were micro enterprises considered because for technology manufacturing it seemed not to be suitable, considering the need of a production facility with a minimum of staff. As one research objective is the provision of a framework to practitioners in marketing, product management, business development, general management and sales, the target group of the questionnaire is the same job area. Therefore responses with other job positions were not considered. After the elimination of errors and the described filtering, according to an applied code book (see Table E-3) and coding instructions (see Figure E-1), 920 responses remained as complete sample.

With the focus on high-technology and medium high-technology industries from developed and emerging countries, 726 responses out of the 920 form the sample of focus. Nevertheless, the general analysis was performed with the complete sample of

920. For the specific research of patterns and variations among the economic regions and industries of interest, the according subgroups were considered.

With the objective of asking knowledgeable experts, who would benefit from the results of the research as practitioners, the level of agreement with the statements representing barrier items was asked for. Subsequently, the barrier variables were computed to form the Likert-type scales described in section 3.4.2. For the coding logic of the formation of the scale variables, the LF-model was used as basis. According to the LF-model and the presented design of the survey, each item is assumed to have the same weighting. The eleven barrier variables (nine from the LF-model and two additional) were computed as the average of the subordinate Likert-type barrier items.

The barrier items and the computed barrier variables were analysed together with the other variables of the questionnaire as described in section 3.4.2. The quality of the questionnaire is assessed as part of the next section.

3.4.7 Reliability and validity aspects of the survey research

3.4.7.1 The quality of quantitative research and objectivity

For qualitative research, a result is valid concerning its source "… if it represents accurately those features of the phenomena that it is intended to describe, explain or theorise" (Hammersley, 1987, p. 69). Therefore, aspects are explained how validity and reliability is achieved by being confident that the source of the information gathering accurately represents the phenomena observed.

For the quantitative part of the research, validity and reliability were assessed by introducing quality criteria, verifying accuracy, relevance, and reliability of the quantitative measurement. Besides validity and reliability as aspects for the quality of quantitative research, objectivity should also be discussed (Rammstedt, 2004). According to Rammstedt (2004), objectivity is the extent to which the result is independent from external influence or factors beside the respondent and can be distinguished in objectivity of execution, analysis and interpretation.

To guarantee objectivity in the execution of a survey, the same setting and environment needs to be achieved for each respondent with a clear description of the procedure. As the procedure is described as part of the previous sections and a self-administered online questionnaire was used, objectivity in survey execution as criteria is regarded to be met.

In order to achieve objectivity in analysis, data coding and error handling needs to be documented in detail to allow repeating the same actions. In addition to the description of the previous section, a coding instruction document had been written with relevant data merging, error handling, filtering and recoding information before the data analysis was performed (see Figure E-1). With this documentation and the usage of closed question formats, objectivity in analysis is achieved.

Rammstedt (2004) suggests detailed descriptions of the scales used and reporting mean and standard deviations of scales regarding objectivity in interpretation. As scaled data handling is discussed and a focus is given to analysing the data with techniques for ordinal data and not interval data, median and mode is reported. Nevertheless, the analysis, referred to in the appendix, additionally shows mean values for potential comparison. With the introduction of the scales used and transparency in showing median, mode and mean, interpretation objectivity can be guaranteed.

Objectivity is one of the three different quality criteria, Rammstedt (2004) explains for scales with multiple items. Discussions of representativeness are also important and included in the following section. The assessment of validity and the reliability of the quantitative data gathering with the survey are explained in the next two sections.

3.4.7.2 Assessing validity and aspects for representativeness

It is important to assess, how well a survey measures what it is supposed to measure. According to Litwin (1995), the validity can be assessed in the forms of face, content, criterion and construct validity. The validity of this survey was assessed in different ways. Several preliminary tests and reviews were performed by academic judges of the research environment, which Litwin (1995) refers to as face validity assessment.

To achieve content validity of the results (Litwin, 1995; Blumberg et al., 2005), subsequent pre testing and pilot testing were performed. The importance of testing a questionnaire is explained by Bell (2005), because aspects like the duration or clarity of questions could be tested. Additionally, it was important to find out, whether the instructions given are clear (Bell, 2005; Fink, 2003). Pre-testing within an academic expert group and a pilot questionnaire directed to the target population helped to guarantee a proper content of the survey by modifying the questionnaire based on their feedback. Feedback of the pre-test of the questionnaire was incorporated into the next test until all feedback was used for designing the actual survey based on the pilot-test with a subgroup of the target population. Furthermore, most of the statements incorporated into the questionnaire are listed in the publication of the LF-model by MacVaugh and Schiavone (2010). Because a number of the statements had been researched empirically by other authors and the LF-model is applied in several publications, this gives also proof for its content validity.

According to Rammstedt (2004), another content-related aspect to be tested regarding validity is the structure of different scales via factor analysis techniques to double-check whether scales represent the same twice. The factor analysis approach was followed regarding the comparison of different loads applying reliability measurements with Cronbach’s α. As one statement decreased the overall reliability due to a too strong dependency with another statement, the needed correction was made.

Concurrent criterion validity can be assessed by verifying whether information can be gathered similarly in comparison to an existing base of information (Litwin, 1995; Saunders et al., 2007) or future information with the attempt of predictions (Saunders et al., 2007). A criterion-related aspect for validity was tested by comparing the frequency of job experience in the sample of the questionnaire[4] with the experience given in the social network of LinkedIn by members holding positions in sales, marketing, business development and product management (≈ 7 Mio.). Thus, the representativeness of the survey results could be evaluated, too. The following graphic illustrates the comparison of results.

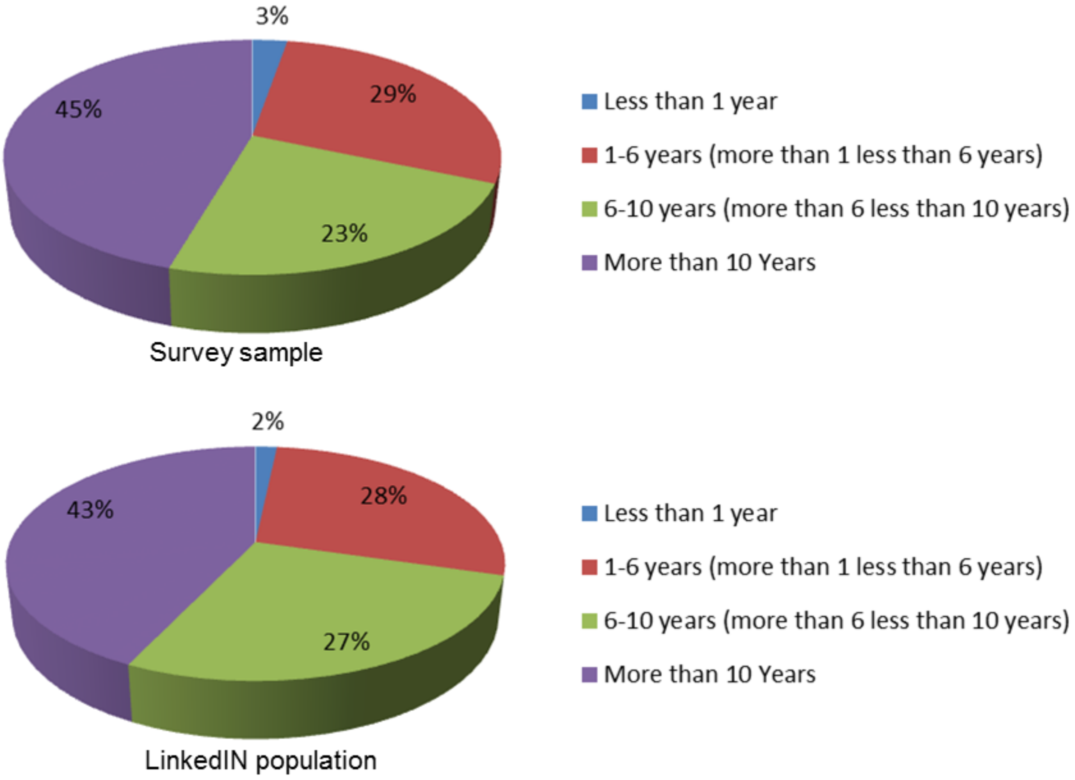


Figure 3-7 – Comparison of sample & LinkedIn population by years of experience

The comparison of the sample of the questionnaire and the population of LinkedIn under the aspect of years of experience shows a comparable distribution with an error margin of 4%. A large number of experienced persons working in according positions in marketing and sales of technology are member of the professional social network of LinkedIn. Nevertheless, it has to be distinguished between a social network and the real world population working in those jobs and industries. LinkedIn is regarded as an

[4] The results of the statistics were extracted from LinkedIn people search filtered for according positions. The possible answers given in the questionnaire and illustrated in LinkedIn did not match. For comparison, a recoding needed to be performed to reduce the levels of details in order to match the different categories given between the research and the LinkedIn information.

established social network for professionals and this criterion shows similar results regarding the frequency.

Regarding validity, face, content and criterion-related aspects for validity were tested and taken into account. Everything possible was performed and additional measures such as filtering were taken to represent the experienced population in according industries of manufacturing technological innovation and according positions sufficiently. The validity is regarded to be assessed and sufficiently achieved.

3.4.7.3 Assessing reliability

The assessment of reliability can be regarded as repeatability. Three forms of its assessment are mostly known with test-retest reliability, alternate-form reliability and internal consistency (Litwin, 1995; Mitchell, 1996; Saunders et al., 2007).

Due to the length of the questionnaire dedicated check questions in an alternative form to other questions were not incorporated to test alternate-form reliability. Nevertheless, logically dependant questions contribute to assessing plausibility for a higher reliability, such as the question of the respondent’s age group and the respondent’s years of experience in their current job. Assuming an average job entry not earlier than at the age of 20, the experience in their current job is limited to the maximum age of their age group subtracted by 20 years (see Figure E-1).

The approach of re-testing was not possible to be applied for all participants of the questionnaire within this research due to the difficulty of asking respondent twice for results resulting in schedule constraints.

The approach commonly used for assessing reliability is by checking internal consistence of the complete survey or a subgroup of questions via Cronbach’s α (Litwin, 1995; Mitchell, 1996; Field, 2005; Saunders et al., 2007).

The test of internal consistency of the set of Likert-type barrier items as the questionnaire´s core was performed with the pilot test and the actual survey results by applying the technique of Cronbach's α (Cronbach, 1951; Mitchell, 1996; Field, 2005). With an α-value of more than 0.7 for the pilot, the result for internal consistency considering was considered to be sufficiently high (Cronbach, 1951; Nunnally, 1978; Field, 2005).

The questionnaire was performed with a properly developed questionnaire design based on the feedback of pre-testing and pilot-testing and achieved quality with validity and reliability. The questionnaire represents the quantitative research methodology of this mixed-methods approach.

3.5 Research plan integrating the chosen methodology

After having taken position concerning the research philosophy and having introduced different applied methodologies as mixed-method approach and the advantages and limits of suitable data gathering techniques, this section summarizes and illustrates the integration of all approaches as a research plan in Figure 3-8.

It incorporates several aspects during the course of research such as applicable industries, the number of barriers, the research method, the according sample and the phase and purpose, illustrated as swim lanes. The purpose of an according phase is described in the swim lane on the right hand side.

The set of applicable industries, illustrated as big oval form on the left hand side of Figure 3-8 can include a group of industries with the same technology intensity (illustrated as circle) or an individual industry (illustrated as dot). A group of industry could incorporate individual industries. The applied industry for a certain phase of the research is coloured in blue.

The different phases of the research, in which different methodologies and data gathering techniques were applied can extend or minimize a set of barriers to investigate. If certain phases minimize or modify the set of barriers, this is illustrated with a funnel. Its swim lane shows a number of red and green forms. The colour code red illustrates different barriers, whereas the colour green represents facilitators for the diffusion of innovation.

The swim lane of research methods illustrates the interdependencies of research methods and if applicable their pilot testing. According target groups are illustrated and described by a box in the swim lanes of the sample used by the research method.

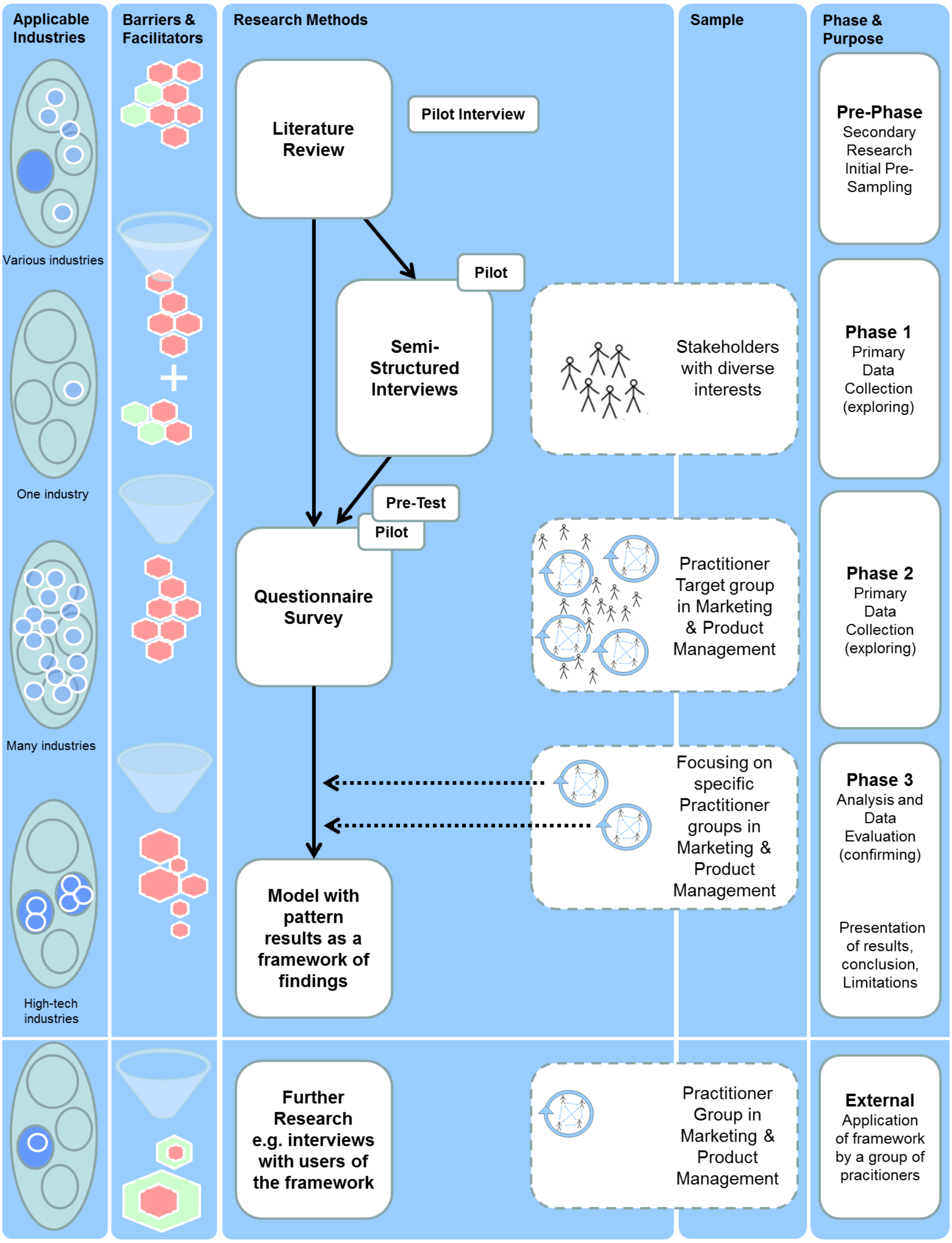


Figure 3-8 – Model of the integrated research methodology

Secondary information was collected in the pre-phase. Literature was reviewed critically for research gaps concerning models and frameworks of diffusion barriers, which could be applied by practitioners. Furthermore this phase consisted of a literature research contributing to the initial case study research. Apart from that, literature for research methodologies was researched in that phase.

Phase one consists of the initial exploratory case study research about the diffusion of digital radio as technology substitution for the classic frequency modulation (FM) technology. This phase focused on a relatively small applied industry. The digital radio industry is considered as small area of an industry group for media production and distribution. Here, semi-structured interviews with stakeholders along the value chain of digital radio were performed. The results of the case study research and the literature review extend the set of barriers and can be used for discussing potential facilitators.

The first phase formed the basis for hypotheses on existence and importance of barriers and questions, whether a generalization is possible to other industries to be researched in phase two. This phase consists of a survey to both test the hypotheses and question whether a generalization could be achieved but also to perform exploratory research on certain patterns of barriers. The target group here was very large with participants of very different industries.

An additional step is illustrated as phase three for detailing the results of the survey. Focusing on a subset of industries (medium high-tech and high-tech industries), patterns emerged and a weighting of barriers was provided, illustrated by its different size. Additionally, hypotheses are confirmed or rejected. The results of this phase provided different weightings of the set of barriers.

Based on the results of the data analysed, modifications to the existing LF-model to the diffusion of innovation are presented referring to limitations of the research and defining further areas for research. The publication of the results including a framework of barriers as illustration and according patterns can be used by practitioners.

Applying the results of the research helps practitioners to evaluate barriers regarding strategic decision-making. To overcome barriers, potential facilitators may be developed. After the phase for detailing the survey results, the illustration shows that the final recommendations (the modified LF-model and variation results of barriers) are directed to practitioners in positions of marketing and product management.

3.6 Ethical considerations

To protect respondents from harm or punitive action, Patton (1990) suggests to keep names of individuals confidential as "…the basic researcher is interested in truth rather than action; it is easier to protect the identity of informants or study settings when doing scholarly research" (Patton, 1990, p. 213).

Because of ethical considerations with any interaction of human beings, the ethics commission for research on humans of the academic environment was informed by an ethics protocol. Possible ethical issues were presented and evaluated to be minor. An approval was received regarding ethical considerations to guarantee the protection of the identities of the research participants. Both qualitative and quantitative research involved only adults, who agreed in advance to participate.

Concerning the qualitative research with interviews, fictionalised names are given to respondents as part of this study. The respondents were told at the beginning of the interview that their names and organizations would not be used in the thesis and that they could withdraw their participation and data given during and after the interview. Additionally, the respondents had the possibility to read the transcription of the interview for potential withdrawing. In addition, a protocol containing the description of the project and ethical consideration aspects was given to participating individuals (see Figure H-1). It was handed out to the interviewees and discussed.

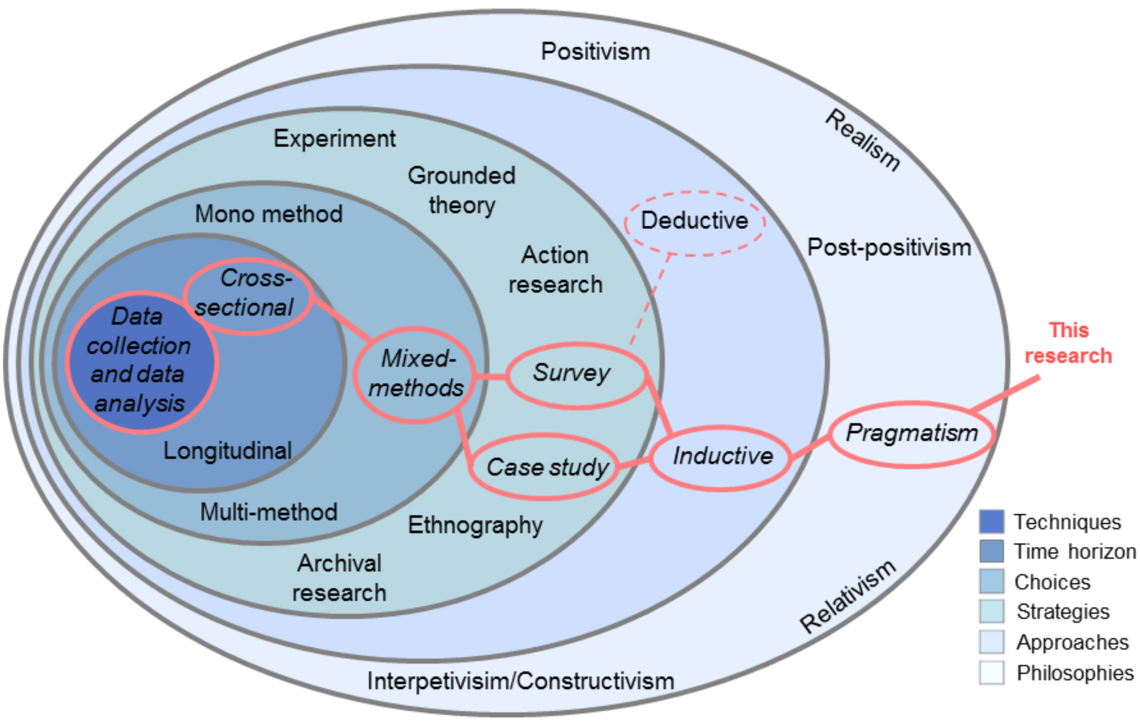
Similarly, any information of the survey with a number of questions is impersonal and no information was used relating to the origin of an organization or an individual during quantitative research. The data of the questionnaire is anonymous and will be kept confidential until it is destroyed after five years. At the first page of the survey, the respondents were explained that they had the possibility to withdraw from the questionnaire at any time and any stage and how the purely academic data would be handled.

3.7 Summary of methodology aspects

This chapter provides a description of the main elements of the study, including the research strategy, the design of the research phases and elements, methodologies and approaches for data collection, sampling strategy and the administration of the research. Any ethical concerns are as well presented. Referring to philosophical research paradigms, the researcher took the position of pragmatism.

A mixed-methods approach was followed to verify the existence and importance of barriers as diffusion challenges for innovation and to identify patterns. The exploratory approach of the two research phases, qualitative research with a multi-site case study research and a quantitative survey, was mostly of inductive nature. Nevertheless some hypotheses were developed for quantitative data gathering and are presented. The analysis techniques used are described in detailed steps.

The following image (Figure 3-9) summarizes different aspects presented such as the philosophical positioning in pragmatism, the mainly inductive research approach, the applied mixed-methods applied and a relation to the time horizon of the research.



Source: Adapted for this thesis from Saunders et al. (2007)

Figure 3-9 – The research onion with methodology and philosophy of this research

The approach resulted in an extremely large repository of information. With a narrow focus (one technology in one national market) and a wide focus (several high-tech industries worldwide). The available data was very diverse.

The research benefits from empirical evidence of case study research and empirical survey data. Qualitative data was gathered and analysed in an exploratory approach to develop hypotheses for potential generalization. Quantitative data was gathered and analysed to test according hypotheses but also to confirm and generalize results of the case study research, presented in chapter four.

Another objective of the research is to develop a framework for practitioners. The collected and analysed data provides evidence for the findings illustrated as industry specific frameworks presented in chapter five. The process of data analysis and evolving the frameworks is a matter of presenting discovered variations.

Regarding research objectives, the presented strategy was appropriate although other research strategies may also be suitable to accomplish results. Quantitative data gathering went well in terms of sample size and response rate. The results are illustrated in the following chapter and a subsequent chapter discusses the results.

4. Results of empirical research

This chapter contains the actual results of executing empiric research according to the research plan (multi-site case study research and survey research). Each section of the mixed-methods consists of important aspects as their objective, their description and the presentation of results. Essential information is described and if needed linked to an appendix or to the applied methodology. Finally the results are integrated following the mixed-methods approach. A separate, subsequent chapter discusses the results.

4.1 Case study research: Digital radio diffusion in Germany

4.1.1 Objective, description and justification of the German case

4.1.1.1 Objective and description of the case study research

The main objective of the case study research is to gather empirical data in an exploratory approach for the LF-model. Therefore, this multi-site case study research is performed questioning which combination of barriers a new technology is facing. Literature refers to a lot of examples for failed technology diffusion. In the last three decades a lot of changes took place in various industries under the buzzword of ‘digitalization’. Therefore, a technology facing this process seemed suitable for contributing to this research.

Used by hundreds of millions of people on a daily basis, FM radio is an analogue technology with a history of almost 100 years (Lessing, 1956; Peers, 1969; Aitkin, 1985; Lewis, 1991; Crook, 1998; Dunning, 1998; Miller, 2010); but it is resisting the substitution trend with digital technology (Vowe & Will, 2004; Steinheber, 2014). Digital radio technologies as a substitution to the classic FM technology have been in place for some years, but they have never successfully created a large market. The question is why new technologies struggle to replace FM radio.

The case study research addresses problems for introducing digital radio with DAB/DAB+ technology (WorldDMB, 2011a) in Germany. The new technology, as a possible substitution for the analogue FM technology provides better sound quality, more choice and additional services such as electronic program guide (EPG) and slide-shows (Kozarmernik, 2004; Garfors, 2010; Garfors, 2011; Brummer, 2010; WorldDMB, 2011a; Anderson, 2013). DAB technology goes back to the 1990s and there were big hopes for its success (Müller-Römer, 1994; Josse, 2002). However, diffusion has not taken place sufficiently and the adoption rate has turned out to be very low.

The German organization KEF in charge of evaluating the need of financial support realised that after a decade of pilot projects and subsidizing, it was not possible to achieve a sufficient rate of adoption and acceptance of the DAB technology among the German population. The introduction of DAB for digitalizing sound broadcasting was declared as failed (KEF, 2007). It was observed that "… the viability of the projects could not be demonstrated" (Goddard, 2010, p. 101). The diffusion of DAB had not achieved a critical mass and at the same time the availability of internet radios had been increasing (Goldhammer et al., 2008).

Although the introduction was regarded as failed, it gained new dynamics in the end of 2010 with an improved version of the technology, named 'DAB+'. Unfortunately, the newer version is not compatible with existing DAB equipment. After two decades of pilot projects, a failed introduction of DAB technology and a lot of discussions about DAB and DAB+, Germany decided to introduce DAB+ on a national level in the beginning of 2011 (Bauer, 2011; MEDIA BROADCAST GmbH, 2011, Anderson, 2013). The author introduces information about the development and introduction of DAB/DAB+ technology in a separate paper (Steinheber, 2014).

For the over 80 million potential listeners in Germany its accessibility, referred to as 'coverage' was approximately 47% (WorldDMB, 2012) at the time of performing the case study research. At the time of finishing the thesis the published number was 78% with one national multiplex (WorldDMB, 2013, 2014). However, the percentage given for coverage is not the adoption rate. It only means that a certain percentage of the population could receive the radio signal but not that they are actually listening to it. With today's availability of high-speed internet, there are alternatives for terrestrial radio (Ala-Fossi, 2010; Steinheber & Chlupsa, 2012, Anderson, 2013), which seem to be ignored by the planning authorities of terrestrial digital radio. After two decades of the existence of DAB and DAB+ technologies as possible substitutes for FM, the diffusion of digital radio has not taken place (Steinheber, 2014).

Although the technology of DAB/DAB+ is relatively old, it can be considered as a sustaining innovation for an existing use case, being subject to the research area of the thesis. The basic usage behaviour of listening to sound is the same, which is why the technology may be classified as sustaining, evolutionary innovation (Christensen, 1997). Drawing similarities with digital TV (Moore, 2006, pp. 10), a new standard, a new frequency and additional services would not be compatible with previous listening behaviours. According to Moore (2006), it would be a discontinuous innovation.

This real-life case study research questions, why the technology was not successful in Germany. Reasons for the failing of innovative technology are researched and combined according to the theoretical LF-model. Constraints and reasons from literature are introduced in the following section, as they may have determined the progress of the diffusion of DAB/DAB+.

4.1.1.2 Justification of empirical data gathering by researching this case

The technology of DAB/DAB+ is described as not having been successfully introduced. Töpfer refers to a failed diffusion (Töpfer, 2008, p. 88), while others describe it as a longlasting periode of decision-making (Goldhammer et al., 2008). The diffusion of DAB/DAB+ has to be seen as a new technology introduced into the economic system of Germany to satisfy a specific function, which is listening to radio. As it is a suitable technology to apply the LF-model, the barriers for digital radio diffusion can be compared to the barrier variables, barrier items and to the domains of the LF-model.

Several publications mention reasons for the failed introduction of the technology as Steinheber (2014). The mentioned reasons can be summarized as follows (Table 4-1):

ID	Challenging problems regarded as barriers	Literature
L1	Sufficient FM sound quality and choice	Töpfer (2008), Anderson (2013)
L2	Bad cost-benefit ratio for smaller radio stations and for listeners	Goldhammer et al. (2008), Töpfer (2008), Anderson (2013)
L3	FM is preferred as technology in addition to internet	Tzschaschel (2011)
L4	Higher utility with DAB/DAB+ not perceived by listeners	Muehlbauer (2008), Anderson (2013)
L5	Receivers for DAB consume more energy and are too expensive without having a different content for most stations	Muehlbauer (2008), Ala-Fossi (2010), Anderson (2013),
L6	Regional governmental restriction	Taylor et al. (2003), Goldhammer et al. (2008), Anderson (2013)
L6	Lack of governmental support	Lawton (2008)
L7	Community of listeners is inclined towards FM	Goldhammer et al. (2008), Tzschaschel (2011), Anderson (2013)
L8	With a missing word-of-mouth effect, a big part of the population simply does not know about the new technology	Töpfer (2008), Anderson (2013)
L9	Lack of industry alliance and cooperation for establishing DAB/DAB+	Goldhammer et al. (2008)
L10	Risk allocated to financial and organizational evaluation concerning switching	Goldhammer et al. (2008)

Table 4-1 – Barriers for digital radio diffusion in Germany mentioned in literature

The IDs used are built with the letter 'L' for literature reference. The majority of the problems listed originate from publications based on theoretical research. Therefore, the barriers derived from literature are analysed with empirical data regarding their existence. A diversity of barriers as reasons for the failed diffusion of digital radio as innovation in Germany is expected as a result of the case study research.

With some theoretical considerations, one challenge lies in the approach of analysing the data regarding the existence of barriers gathered from the interviews, which have been introduced in the chapter of methodology. The analysis was performed by applying meta-matrices and results are presented in the next section. Based on the results of the case study research, the domains of MacVaugh and Schiavone (2010) are applied as categories of technology-related aspects, aspects of the social structure and aspects of learning to use and to appreciate a new technology.

4.1.2 Development of resulting clusters

An overview is achieved for the diversity of challenging problems with the results from the case study research. Four tables were created during the analysis of the interviews for illustrating barriers for the diffusion of digital radio with DAB in Germany, of which three follow the approach of Miles and Huberman (1984) with the meta-matrices found in Appendix I. The analysis and the data created during the interviews are performed by an unordered meta-matrix; a partitioned meta-matrix (see Table I-1 for their structure) and a final clustered meta-matrix (see Table I-2).

The filling of the tables required a detailed assembly of data in a way that coherence is produced across the sites representing different parts of the value chain. The mentioned tables present results from the analysis of 16 semi-structured interviews forming four different sites of the value chain for the case study research. The amount of data is illustrated by dimensions of the initial meta-matrix (see Figure I-1) and its partitioned subset (see Figure I-2).

The matrices created were analysed with the main goal in mind of understanding why the diffusion of digital radio with the standards of DAB and DAB+ was not a big success in the German market for radio. The unordered, partitioned data of the semi-structured interviews were analysed to identify clusters regarding challenging problems and barriers for the diffusion of digital radio in Germany.

An evaluation was also performed by the interviewees regarding the most critical problem for the diffusion. Whereas the clusters are illustrated in detail in Appendix I (see Table I-2), an overview is given. As the following table identifies, the complete list of clusters is not considered to be a barrier for the diffusion. The first cluster in the table represents important evidence that the diffusion struggled. The rest of the clusters represent problems for the diffusion of digital radio. Each cluster is presented with an ID as reference, built with the letter ‘C’ for cluster.

ID	Challenging problem mentioned	Evaluation as barrier
C0	No diffusion achieved	Not a barrier but evidence for non-adoption
C1	Missing benefit and no added value	Yes, most important barrier
C2	Missing inter-industrial collaboration (for solving the Chicken and Egg problem)	Yes
C3	Lack of marketing	Yes
C4	Missing recognition of the technology	Yes
C5	High costs for replacing the old technology	Yes
C6	Internet as a technological substitute (possible leapfrogging)	Yes
C7	Missing governmental support	Yes, but rather facilitator
C8	No green perception	Problem but not regarded as a diffusion barrier
C9	Missing upgradeability	Problem but not regarded as a diffusion barrier
C10	Regional constraints due to political history (Difficulty in availability or access)	Yes
C11	FM technology as global standard	Yes

Table 4-2 – Identified clusters of diffusion challenges for digital radio in Germany

The clusters of C8 ('no green perception') and C9 ('missing upgradeability') were mentioned as challenging problem but were not considered as serious problem for the diffusion of digital radio. The following graph with an intersecting set illustrates that some barriers described in literature are confirmed by the case study research.

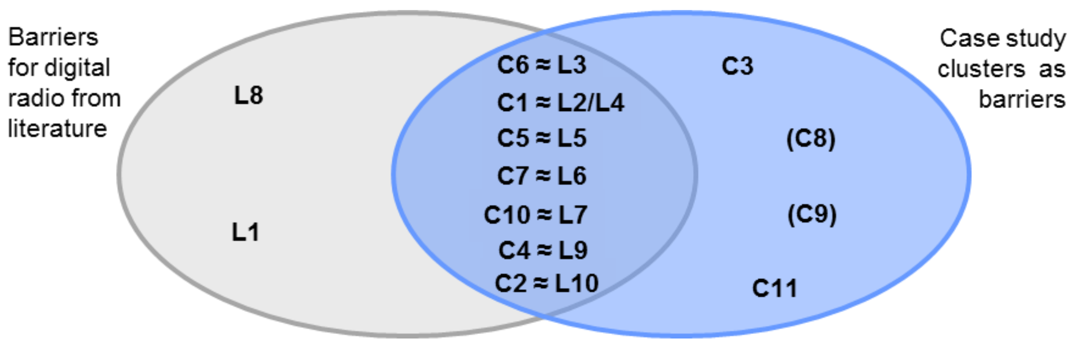


Figure 4-1 – Intersection of diffusion barriers in literature and case study research

The clusters which represent barriers are explained in detail referring to interviewees (see Table I-1) and statements of the meta-matrices of Appendix I. The explanations of barrier clusters refer to LF-model variables and a mapping is illustrated in section 4.1.4.

4.1.3 Barrier clusters identified for the diffusion of digital radio

4.1.3.1 Missing benefit and no added value

The fact that digital radio is not perceived to provide a higher utility turns out to be the most important barrier due to cluster C1 ('missing benefit and no added value'). Although the new technology allows a higher availability of channels, most of the contents were already accessible via FM. Radio listeners have usually had their favourite channel for years, which they will continue listening to whether it is via a new technology or not. This was commented as follows:

"This is something they already have and with some stations they would even get less."

(EdMediaMana)

The technology was sold as having a higher sound quality but people didn't care about that; quality was not perceived to be an added value. (RadioFut, NetProv, EdMediaMana). Unfortunately, quality was even worse at the beginning, which is why some individuals developed a negative orientation towards the technology and used other technologies (EdModContent, AdvSalesMana, ModeratorDAB, and TransManu).

"… it hasn't achieved in showing people that it's something better than normal FM radio."

(ModeratorDAB)

As listening to radio is often referred to as a background application in parallel to cooking, working or car-driving, a conscious perception of a higher sound quality is only an important aspect for a small percentage of listeners as this statement shows.

"Because driving in the car, you have so much different noises around you, I think the quality and some distortions in the signal are not that important to most of the listeners."

(TransManu)

As listening to radio in comparison to watching TV does not require the total awareness of senses, additional services are mostly not needed and are not perceived as valuable

(EdMediaMana, AdvSalesMana). The use of radio simply focuses attention on listening and not on those more complex services. The fact that listening to radio mostly means listening passively and absent-mindedly seems not to allow a higher quality to be perceived either (EdMediaMana, TransManu).

Most of the additional services of DAB (information on artist, radio station, program or weather) are also available via mobile internet as an adjacent technology (EdModContent, AdvSalesMana, and TransManu). Young generations have a high interest in media via the internet, such as YouTube and Facebook (ExModMarketer, RecManu).

4.1.3.2 Internet as a technological substitute (possible leapfrogging)

The aspect of leapfrogging is mentioned with the dominance of internet. There is awareness among individuals and communities of the future availability of a better technology. Smartphones provide services via mobile internet connections making the potential added value of DAB obsolete. Besides additional services, listening to radio as basic application seems to have its future as well with internet. This is already the case for a stationary application with IP streaming. As it already works in areas of high speed mobile internet connections, it might be the technology substitution both for FM and DAB. This is already a topic in the automotive industry:

"More innovative technologies are already existing: " If you want to have a digital DAB receiver or a, let's say LTE capable device, which can receive your Spotify or any other music platform content, then at least the young people would rather go for the LTE technology because you have more possibilities with that."

(TransManu)

Thus, FM combined with the benefits of a future even newer technology may be perceived as better than DAB as a new technology. Because this new technology is in sight, people are "… looking what the internet offers" (RadioFut). During decision-making, there is "…a fight between FM and DAB or recently, more latest the fight between IP radio and digital radio" (ChipManu). The decision-making may be postponed, as the following statement shows:

"At the moment we force the user of a digital radio to think very hard about how they want to listen, on FM, or DAB or on IP"

(ContentPlay)

When the decision against a DAB receiver is because of something newer coming, this is referred to as leapfrogging. This dilatoriness can be a major problem for the diffusion of an innovation. If the diffusion of a technology takes very long and no contagion is achieved, the probability of even better technologies being available increases.

4.1.3.3 Replacing old technology being too expensive

Because of missing benefits and the availability of similar services online, individuals are not ready to pay a higher price for standalone receivers. (EdModContent, EdMediaMana, TransManu). Equally, it was expensive buying DAB as receiver option when purchasing a new car (AdvSalesMana, ExModMarketer, TransManu). Taking prices into account by cluster C5, the total utility of the technology is not perceived to be higher than the old technology.

Taking listeners aside, the utility is also not perceived by radio stations. Local or small radio stations have limited resources. The ratio of effort and effect for digital radio via DAB in comparison to FM radio and the interest of young listeners in other types of media are reason enough, not to focus on DAB. The new technology may exceed the measurable technical specifications of FM, but the measurable non-technical specifications as cost and number of listeners to be reached are not exceeded. Thus, considering the trade-off between infrastructural costs versus benefit as utility maximization especially for commercial organizations, there is not a higher total utility (ContentPlay, RadioConsu, ChipManu). For broadcasters "…the cost to acquire is too high versus the value, too specific but not enough" (IT infrastructure).

A similar situation had to face the car manufacturing industry, as R&D effort is quite immense regarding costs and schedule to incorporate suitable receivers into a new car (CarManu).

The diversity of given aspects support the barrier item of a technology's utility not being perceived as higher than the existing old technology for the domains of individuals and the community. As the market diffusion of FM is that strong, the industry struggles with introducing the new technology as the following section shows.

4.1.3.4 FM technology as global standard

While FM is a global standard for radio, DAB is only partially in operation in Europe and among the countries there are variations. One country applies the standard of DAB whereas another country uses DAB+. Germany first applied DAB than changed to DAB+. If DAB was the only global standard for digital radio in terrestrial broadcasting, there would be a scale effect in the manufacturing of equipment.

One main challenge is to replace a technology which has been in place for about 80 years and is applied worldwide. Referring to cluster C11 ('FM technology as global standard'), infrastructure and receivers are available in huge numbers, which makes it difficult to have the old technology replaced, as the following statement shows.

"It's difficult to replace (…) the old FM networks in Germany, because there are (…) 350 million FM receivers in the market."

(TransManu)

FM as old technology is a well operating global standard of mass media, whereas DAB is regional and difficult to be replaced (EdMediaMana, InfraServiceAUS, TransManu). The existing old technology is used in parallel to the adjacent internet technology and both listeners and radio stations adapted to this by providing additional information with online applications (EdModContent, AdvSalesMana, TransManu). The complementarity of the older technology results in a higher total utility as no listener had to replace all of their receivers on a global level:

„And of course the FM will still be here for many many many years to come. (…) You cannot expect everyone to go out and purchase digital radios. “

(InfraServiceAUS)

Because the old technology is still very effective (CarManu, TransManu), considering its worldwide availability, millions of receivers are in the market. In Germany with more than 80 million people, the old technology is established and in daily use. Therefore, even DAB-only radio stations realised, they needed to use the old technology as the following statement illustrates:

“We need the old technology, if we don’t get the old technology the whole radio will fail.”

(ModeratorDAB)

Having such a high market penetration with the old technology of FM being compatible with a huge diversity of electronic devices in big numbers, it is difficult to replace such a technology. The complementarity of the old technology results in a higher total utility for many individuals forming the community of users in Germany.

A lot of DAB radio receivers seem to look like FM receivers. FM technology has been dominating the receiver design over many decades (Steinheber & Chlupsa, 2012). The following statement explains FM as established technology with a dominant using behaviour:

"FM is very popular and the usability of FM is well known. Everybody is aware of the use and FM radio".

(ChipManu)

As the old technology is very popular and forms a strong and in Germany well-working network industry, there is the dilemma of introducing a new technology in a variety of complementary products at the same time.

Due to the circumstance that the old FM technology is still used at the same time, referred to as ‘simulcast’ (AdvSalesMana, ModeratorDAB), a big diffusion was not achieved. The future of radio is perceived as being a hybrid (ContentPlay, RadioFut) as the following view illustrates:

"... have a look at hybrid radio. The concept of actually from a user's point of view forgetting whether they are tuned in on FM or DAB or the internet, it doesn't actually matter. "

(RadioFut)

The suggestion of hybrid radio shows that the design is still dominated by FM technology and its usage behaviour. A dominating new design is not achieved with DAB regarding the complementarity of the technology in the network industry of radio.

The question of complementarity of a new technology is followed by the question how diverse the number of stakeholders and related organization is to form a working network industry satisfying the need for complementarity.

4.1.3.5 Regional constraints due to political history

The introduction of a new technology with a high impact on infrastructure, content creation, electronic consumer industry and the listening behaviour of millions of listeners in a population such as in Germany requires a good planning and cooperation.

One of the reasons for the need of good management for cooperation is the political history of Germany referring to cluster C10 (‘Regional constraints due to political history’), which made a nationwide access and setting up of the technology difficult.

No national broadcaster was allowed by the Allies after the Second World War within Germany (RadioFut, ITinfrastructure). Since then, the German government has not overcome this constraint until 2011 (Bauer, 2011). Therefore, the individual regional broadcasting organizations tried for a long time to follow their own organizational targets and objectives. A lot more organizations and people are involved in decision-making (RadioConsu). The following section outlines another barrier which may be a key to overcome such constraints.

4.1.3.6 Missing inter-industrial collaboration

The mentioned constraint of the previous section mainly refers to the broadcasters, whereas cluster C2 (‘missing inter-industrial collaboration’) refers to a bigger variety of stakeholders which should cooperate. Apart from broadcasters, one main player in the market is the car manufacturing industry, as a significant percentage of radio listening takes place when driving a car especially in Germany. Important car manufacturers (e.g. BMW, AUDI, VW, etc.) are from Germany and the incorporation of suitable receivers in a new automobile needs some effort (CarManu). Time plans for launching a new terrestrial broadcasting standard and having receivers available in new automobiles should be in line. If no signal can be received, nobody would pay for an option within a new car or would buy a portable receiver. This is often referred to as ’Chicken and Egg‘ (NetProv, RadioFut, ContentPlay, RecManu, EdMediaMana) problem, as the following explanation illustrates:

"The industry says: Why should we produce receivers, since there is no content whereas the broadcasting stations claimed that it didn't make sense start broadcasting without sufficient receivers in the market."

(RecManu)

Additionally, content was missing when infrastructure and receivers were there (RecManu, NetProv). This should outline that the launch and marketing of DAB as new radio technology in terrestrial broadcasting should be coordinated between radio stations and also retailers to have a more effective marketing communication. Unfortunately, this has not been perceived by a lot of listeners according to some industry experts (ChipManu, StandForum). The public broadcasters may have preferred the status-quo to prevent additional competition entering the market (RadioConsu, RadioFut), which is why there was no big push from their side.

Therefore, the collaboration within one industry and even across industries is a very important aspect. After failed efforts, the one or the other industrial company might be oriented towards the old technology of FM again as one DAB station explains

(ModeratorDAB). If this happens widely, whole industries can be oriented towards the older technology, which is seen as major barrier for digital radio (RadioFut, StandForum).

Missing industry collaboration between stakeholders of car, receiver and transmitter manufacturing, infrastructure provider and content dominating radio stations is referred to as one of the biggest barriers for the diffusion of digital radio in Germany (RadioFut, ChipManu, CarManu, ContentPlay, StandForum, and TransManu).

4.1.3.7 Missing governmental support

The previous section describes that industrial cooperation was missing. If asked how to overcome this situation, the answer can be as follows:

"Yes you need to have an industry that is talking to each other and you need to have leadership from somewhere."

(ContentPlay)

The requested leadership has not been there in Germany in comparison to other countries, where the government decided on clear switch-off dates for the old technology (RecManu, RadioFut, and CarManu). Without a technology push by a governmental institution, the introduction of the technology seems to be difficult as the cluster C7 (‘missing governmental support’) indicates by the following statement:

"... you should have (...) Governmental help and governmental pressures to shut down the classical way, because then you have to react, then everybody has to react.”

(AdvSalesMana)

The industries would hardly accept the new technology without governmental pressure but there may also have been an influencing organization in favour of other technologies interacting with proprietary institutions (StandForum).

In addition to the missing industry collaboration which could have been overcome by governmental support, another barrier is explained in the following section with the missing word-of-mouth effect among radio listeners for DAB technology.

4.1.3.8 Missing recognition

To achieve a high diffusion for the replacement of FM, a strong word-of-mouth effect is needed. That this is not achieved is shown by cluster C0 ‘no diffusion achieved’. The arguments are related to limited interest among early adopters (NetProv) and due to the fact that a lot of people simply do not know it (RecManu). The rate of adoption in the first decade after its introduction continued to be very low and contagion is therefore weak as the following statement demonstrates:

“…the adoption rate for analogue film shooting to digital cinema, the conversation rate, which is about 70% of shooting today is done on digital cinema.(...) look at the amount of listeners, or the amount of producers that produce in the context of digital radio, that amount is still very, very low"

(ITinfrastructure)

Cluster C4 (‘missing recognition of the technology’) represents a weak contagion even more strongly. Most people just do not know DAB standards as the new technology (RecManu, ModeratorDAB). A worst-case perception of some respondents to the interviews is that receivers are only among people who work in positions related to the broadcasting industry and "…even within the radio station, people are asking what is DAB and what are the benefits?" (AdvSalesMana). The biggest problem of the missing recognition is the long time that the technology theoretically needs for its diffusion (CarManu, RecManu, and ContentPlay). The diffusion of DAB is not taking place "…while the world is turning" (ContentPlay). The DAB standards are meanwhile perceived as an old technology in our fast-moving times because its diffusion took too long (TransManu). Compared to FM as old technology "…on the one hand it's modern, on the other hand it seems very old fashioned" (ModeratorDAB).

There may be several reasons why there was no recognition of the new technology. One of the reasons might be in a lack of marketing, which is referred to in the following section.

4.1.3.9 Lack of marketing

There are various aspects to mention referring to the quality of marketing of DAB standards as the new technology. One reason for the low contagion may also be a missing green perception as desired by WorldDMB (2011b). Cluster C8 (‘no green perception’) shows that the technology of DAB standards is not perceived as being greener than FM (AdvSalesMana, EdMediaMana, ContentPlay, and RadioConsu). However, listeners would probably not care according to industry experts although it was marketed as environmentally-friendly (NetProv, StandForum, RadioFut and TransManu). Nevertheless, there would have been the possibility to address the environmental awareness of potential listeners in Germany (CarManu, RecManu).

The question which elements were used in marketing is based in the domain of market and industry according to the LF-model. Cluster C3 (‘lack of marketing’) refers to different approaches for marketing the DAB standards as the new technology in order to achieve sufficient contagion for a successful diffusion among radio listeners in Germany. One aspect raced was simply that there was not a lot of marketing (ModeratorDAB, ExModMarketer, EdModContent, AdvSalesMana, EdMediaMana, ContentPlay, NetProv, ChipManu, and RecManu) and open questions remained about the benefit of it (CarManu). In addition to that, the strategic decision which added value should be communicated to German listeners can be questioned, because for example a higher sound quality as already explained in section 4.1.3.1 is not perceived as higher utility. The following statement underlines this argument referring to choice:

“…marketing was focused on the transmission made by the people in charge of the transmission: marketing has been focused on choice, which was not important (…) marketing has been focused around something which has not been very, very important. Therefore most of the people that look at the marketing of the digital radio do not understand why it would be interesting for them."

(IT infrastructure)

As no strong contagion has been achieved although the technology was re-launched in Germany in 2011 with a technological update, there is still the need to inform masses about the benefits. The marketing, which was performed, was focusing its arguments on the technology and not the benefits for the listener (ChipManu, ITinfrastructure, NetProv, ChipManu, EdModContent, and ModeratorDAB). In addition to that, the aspect of cluster C2 ('missing inter-industrial collaboration') explains as well the importance when launching related to marketing, as the following statement supports:

"…having promotion for digital radio without having the retailers informed, which was the case, and without having attractive products in the shops, which was the case, (...) it would also not create a market!"

(ChipManu)

One of the biggest dilemmas seems to be the situation that additional content is not perceived as benefit. One aspect is already covered in the barrier of not having perceived a higher utility with the new technology in section 4.1.3.1 related to choice and the listening behaviour. Another aspect is that the choice is not tremendously higher compared to the introduction of digital TV (ITinfrastructure). At the beginning the marketing idea was even to promote digital radio as new technology through the old technology in a simulcasting approach. Some respondents see a big marketing mistake made in some regions because "…first DAB stations were offered FM frequencies to have the possibility of promoting the new technology via the old technology" (EdModContent). Such marketing decisions destroyed added value at the beginning.

The diffusion of DAB struggles, as the concept of it relating to a higher utility is already questionable. Now it is difficult to follow a marketing strategy, since there are barely any benefits left which could be perceived as added value by listeners. With a success limit for marketing the technology, a weak contagion remains which cannot displace the existing norms and complementarity with the old technology.

Poor marketing as a barrier (discussed in this section) and the other barrier clusters (from the previous sections) were identified as barriers for the diffusion of digital radio as subject of the case study research. The following section describes clusters, which were not identified as barriers.

4.1.4 Further clusters as challenging problems for digital radio

The further cluster C9 (‘missing upgradeability’) describes that those users, who have adopted the technology by purchasing DAB receivers cannot use or upgrade their equipment to receive DAB+ signals:

"So DAB Plus receivers work on DAB and DAB+. The DAB radios will only do DAB…”

(RadioConsu)

Especially in the last decades many technologies in electronic equipment, containing processors or programmable logics, allow certain upgradeability via firmware updates. Unfortunately, DAB technology does not as the following statement shows:

"... the kind of codecs that DAB use have been updated (…) You cannot do over the air software updates to put a new codex in to your radio. You are stuck with the original MP2 codex from 1985."

(ContentPlay)

Individuals who purchased equipment for DAB had to face big disappointment when DAB+ was introduced (CarManu, EdModContent). The missing upgradeability was neglected to be an important reason for non-adoption in Germany, as only a very small number had purchased DAB receivers (AdvSalesMana, EdMediaMana).

Another cluster identified during the analysis is C8 (‘no green perception’). The aspect that the new technology is not perceived as being more environmentally-friendly is not seen as a barrier or problem for the diffusion of digital radio. Therefore, this cluster is not identified as being a barrier. However, it could have been marketed as such.

Thus, cluster C0 (‘No diffusion achieved’), cluster C9 about a missing upgradeability or adaptability and cluster C8 about the perception of the technology being greener are not regarded as barriers. Those regarded as barriers are mapped against the barriers of the LF-model. This is presented in form of summed indices, consisting of the mapped result, as explained in the following section.

4.1.5 Contribution of clusters to barrier variables of the LF-model

The appendices of the unordered meta-matrices and the list of barrier clusters show that quite a diversity of problems exist for the diffusion of digital radio in the German market.

With the identified clusters a mapping to the barrier items, barrier variables and domains of the LF-model (MacVaugh & Schiavone, 2010) is performed. The following table (Table 4-3) illustrates the mapping of barrier clusters to the barrier variables, while the mapping with barrier items can be found in the appendix (see Table I-3). The vertical axis gives the different barrier variables, whereas the horizontal axis shows the different clusters identified.

	C2 - Missing inter-industrial collaboration	C3 - Lack of marketing	C4 - Missing recognition	C1 - Missing benefit & no added value	C5 - Replacing old technology too expensive	C6 - Internet as a technological substitute (possible leapfrogg.)	C7 - Missing governmental support	C8 - No green perception	C9 - Missing upgradeability	C10 - Regional constraints due to political history	C11 - FM technology as global standard
Utility				+IC	+IC	/+IC					
Complexity				/+IC	/+M						
Complementarity						/+IC					+ICM
Social context							/+M			+M	
Orientations	(+M)			/+IC			/+M				
Contagion		+M	+IC								
Learning capacity											
Learning capability											
Costs for learning											

Table 4-3 – Mapping table of interview clusters against LF-model barrier variables

The table shows that the barrier clusters can be mapped and related to the barriers of the LF-model and to its domains ('I' for individual, 'C' for community and 'M' for the market/industry domain). The barrier clusters mainly were mapped to barrier variables of the conditions of social structure and technology. Barrier clusters which contribute to a LF-model barrier but do not represent a strong confirmation are illustrated with a positive tendency of '/+'.

Several barrier clusters are mapped against a single barrier variable from the LF-model. However, there are additional clusters which relate to several barrier variables. Apart from the unconsidered clusters, most clusters support the barriers from the LF-model for the diffusion of digital radio in Germany. The mapping evaluation in brackets illustrate that a mapping towards the barriers of the LF-model could not be performed but the model structure would allow a mapping.

Against the barrier variable of *utility* of a technology, several barrier clusters are mapped relating to one subordinate barrier item. Cluster C1 can be mapped to this barrier as there seems to be a missing benefit and no added value is perceived. Moreover, cluster C5 can be mapped to this barrier, as the replacement of current radio receivers by new ones is too expensive. Thus, the total utility of the technology is not perceived as higher than the old technology. A further barrier cluster (C6) represents the awareness among individuals and communities of internet as a potential substitute for FM and digital radio via DAB/DAB+. The utility of the old technology combined with the benefits of internet may be perceived as even better than DAB/DAB+. The three clusters (C1, C5 and C6) describe that DAB is not perceived to have a higher utility but higher costs.

The *complexity* of the technology is another barrier variable, against which two clusters are mapped to. With the barrier cluster describing a missing benefit and no perceived added value (C1), the main attention is on an old use case, which is listening to radio in a passive way and not actively appreciating the newest feature. Another aspect comes with the barrier cluster C11 ('FM technology as global standard'). Although the standard of FM technology was introduced several decades ago, the product life cycles of receiver technology especially in the automotive industry are quite long. It seems to be difficult to introduce the new technology of digital radio into those products. The barrier clusters (C1 and C11) supporting the variable of *complexity* only provide weak confirmation of the barrier variable.

The strength of the older FM technology as a global standard (cluster C11) can be mapped to the *complementarity* of a technology as barrier variable as FM has dominated the design of radio receivers worldwide and its worldwide complementarity results in a higher utility. The case study research findings refer to a chicken and egg problem, which is also referred to as 'lock-in situation' (MacVaugh & Schiavone, 2010, p. 200) especially in network industries (Shapiro & Varian, 1999). This situation relates to the complementarity of the technology. As DAB does not lead to a dominating design, while FM is still dominating, the subordinate barrier item of the barrier variable of *complementarity* is represented by barrier cluster C11. Furthermore, the new technology does not result in a higher total utility as FM technology is widely applied and potential added values can be accessed via other media. Barrier cluster C11 supports the complete barrier variable of complementarity with its subordinate items.

Within the *social context* of the social structure, the barrier item of the domain of industry and market is supported by cluster C10 ('regional constraints due to political history'). The regional constraints have restricted the access on behalf of the state. Thus, only some states as social subgroups were initially able to access digital radio technology, implemented as trials. For a long time, no similar nationwide possibility of access was possible. This problem could have been overcome earlier by adequate governmental support, described as a facilitating cluster.

Three barrier clusters are illustrated in the mapping table to be mapped against *orientations* as a barrier variable. Barrier cluster C1 ('missing benefits & no added value') provides a weak confirmation for the barrier items of the individual or community, because the one or the other developed a negative orientation towards the technology as the quality was bad at the beginning and as consequence people listened to CD, mp3s or FM. In contrast to that, barrier cluster C2 (‘missing inter-industrial collaboration’) seemed to be a serious diffusion barrier in the perception of the interviewees. Intending to classify this barrier as important diffusion problem of digital radio in Germany into the domains of the LF-model; it has to be pointed out that neither the domain of individuals nor the domain of a community of individuals applies. The barrier cluster is illustrated in brackets as a mapping to a subordinate barrier item of the barrier variable is not possible. However, this barrier can fit in the industry/market domain of the barrier variable of *orientations*, because the one or other industry was not towards the technology of DAB or DAB+ in a suitable time window. The chicken and egg problem due to ‘missing inter-industrial collaboration’ could have been solved by governmental support.

No higher utility and a missing complementarity of the new technology might be some of the reasons, why contagion with the new technology is not strong enough to achieve a substitution of FM as a global community norm. This is represented by the barrier variable of *contagion*. The barrier clusters C3 (‘lack of marketing’) and C4 (‘missing recognition of the technology’) can be mapped to the according barrier item of this variable. A lack of marketing digital radio and marketing errors from the past related to the domain of the market and industry on a macro-level, whereas a missing recognition relates to the domains of individuals and the community. The two barrier clusters describe that DAB has not achieved a strong contagion, e.g. because of a lack of marketing.

Cluster C9 describes the missing upgradeability from an initial version of the technology to a later version of the same technology. The cluster of upgradeability or more general adaptability may relate to *compatibility* as barrier variable from the LF-model but as it is regarded as no serious problem for the diffusion, it was not mapped. Cluster C8 (‘no green perception’) relates to the barrier variable of contagion and the subordinate item of marketing. The environmental awareness of the German population could have been addressed by marketing. But cluster C8 was also not considered as problem for the diffusion of digital radio. However, the aspects of adaptability and environmental awareness may be important for other technologies.

Problems with learning aspects for digital radio are not sufficiently referred to in the interviews for a cluster to evolve. Some interviews do refer to the effort of learning, e.g. potential listeners had to go to a shop with good receivers to learn about the technology and how to use it, but it was not considered as reason for non-adoption.

Having mapped the barrier clusters from the case study research against the barrier variables of the LF-model, the following section presents an overview of resulting barrier items according to the LF-model.

4.1.6 Resulting LF-model barrier items supported by barrier clusters

The previous sections show the development of clusters (C1, C2, …) and the identification of those clusters, which according to the interviewees were important and relevant barriers for the diffusion of digital radio in Germany. Subsequently, the barriers were mapped to the barrier variables of the LF-model. In addition to the mapping table with barrier variables, a detailed mapping table with barrier items is provided (Table I-3).

The summed indices of the previous section illustrate the references between the identified barrier clusters and the barrier variables of the LF-model. As several barrier clusters support the LF-model regarding the mapped barrier variables as a strong confirmation, this section provides an overview of resulting barrier items.

The barrier items are presented with the wording of both, the LF-model and the dominating supporting barrier cluster. Cluster C0 supports all barriers and barrier clusters, as it refers to the fact that no diffusion was achieved.

The following table (Table 4-4) lists the barrier items and identifies the dominating supporting barrier cluster in bold and underlined. The used IDs are built with the letters ‘LF’, if the identified barrier is a limiting factor as part of the LF-model.

ID	Barrier items for digital radio identified in the LF-model	Supporting barrier clusters
LF1	No perception of digital radio (DAB) as technology of higher utility but of higher costs	**C1**, C5, C6
LF2	Complementarity of FM results in higher total utility	**C11**, C6
LF3	Digital radio (DAB) does not lead to a dominating design due to the global availability of FM	**C11**
LF4	Constraint of regional access on behalf of proprietors	**C10**, C7
LF5	No contagion of digital radio (DAB) among listeners	**C4**
LF6	Lack of marketing and marketing errors in the past	**C3**
LF7	Focus of attention is on listening radio not on newest service	C1
LF8	Complexity of radio industry renders really new innovation less frequent	C5
BI1	Lack of industrial alliances for consensual orientation towards digital radio (DAB)	**C2**, C7

Table 4-4 – Identified barrier items for digital radio in Germany according LF-model

All barrier items except BI1 can be found in the LF-model. Most of the barrier items (LF1 to LF6 and BI1) are regarded as barriers with strong confirmative reference by the underlying barrier clusters. Barrier items with a weaker reference in subordinate barrier clusters describe the barrier items of the LF-model variable of technological *complexity* (LF7 and LF8).

As the LF-model does not contain a barrier item for the macro-level domain of the industry concerning negative orientations, the barrier item BI1 is listed apart. The authors of the LF-model argue that a single market would always be oriented in a positive way due to possible profit (MacVaugh & Schiavone, 2010; MacVaugh, 2012). Taking the existence of adjacent markets into account, this gap can be filled by the consideration of the barrier item BI1 with the evidence of the barrier cluster C2 (‘missing inter-industrial collaboration’).

In conclusion, the cluster analysis of the case study research evolves nine clusters, described by the interviewees as barriers for the diffusion of digital radio. With mapping the barrier clusters to the barrier variables of the LF-model and with forming barrier items with a suitable wording, nine barrier items can be classified with the LF-model. Considering BI1 as an additional barrier item as subject for extending the LF-model, the case study research evolves ten barrier items.

All barrier items as part of the LF-model and further barrier items such as BI1 are researched as part of the quantitative research approach of an online questionnaire. For each barrier item, a general statement is evaluated by practitioners from different industries. As the survey was also directed to people working in the media production and distribution industry, a confirmation of the case study research results can be performed. The survey results are presented in the following section.

4.2 Survey to practitioners of technology marketing & sales

4.2.1 Objective and justification of questions selected

The main objective of the survey is to gather empirical data mainly following an exploratory approach for the existence and importance of barriers as part of the LF-model and additional barriers for the diffusion of innovation and according differences.

Therefore data gathering was performed via this survey questioning experts of different industries having to market innovation in high-technology, which barriers a new technology might be facing based on their industry experience. The questioning was performed as a list of statements for barrier items mostly originating from the LF-model, to which the respondents gave their level of agreement.

A focus of the quantitative research is on manufactured high-technology, such as in medical equipment, automotive or electronic manufacturing. While the subject of the case study research was on one technology, the survey addresses industries with very different technologies.

The type of product, technology-intensive industries and the economic environment may show differences regarding the perceived importance and relevance of barriers. Therefore those aspects were asked in addition to barriers. Furthermore, demographic data was asked for such as their age group of the respondents, their country of origin or their education. This data is used to analyse the sample generally and to evaluate the value of the answers.

The survey addresses the challenging problem of technology substitutions and the diffusion of innovation with new technology in different industries. The results of this quantitative research by an online questionnaire are illustrated in the following sections. With the filtering described in section 3.4.6 and after error elimination, the results can be described initially focusing on demographical aspects.

4.2.2 Demographic information

The online questionnaire was answered by more than thousand respondents from more than 50 countries all over the world. After elimination of erroneous responses, the responses were filtered for the target group of persons working in sales and marketing of technology for manufacturing companies from all over the world. The following map (Figure 4-2) shows a regional distribution of the respondents.

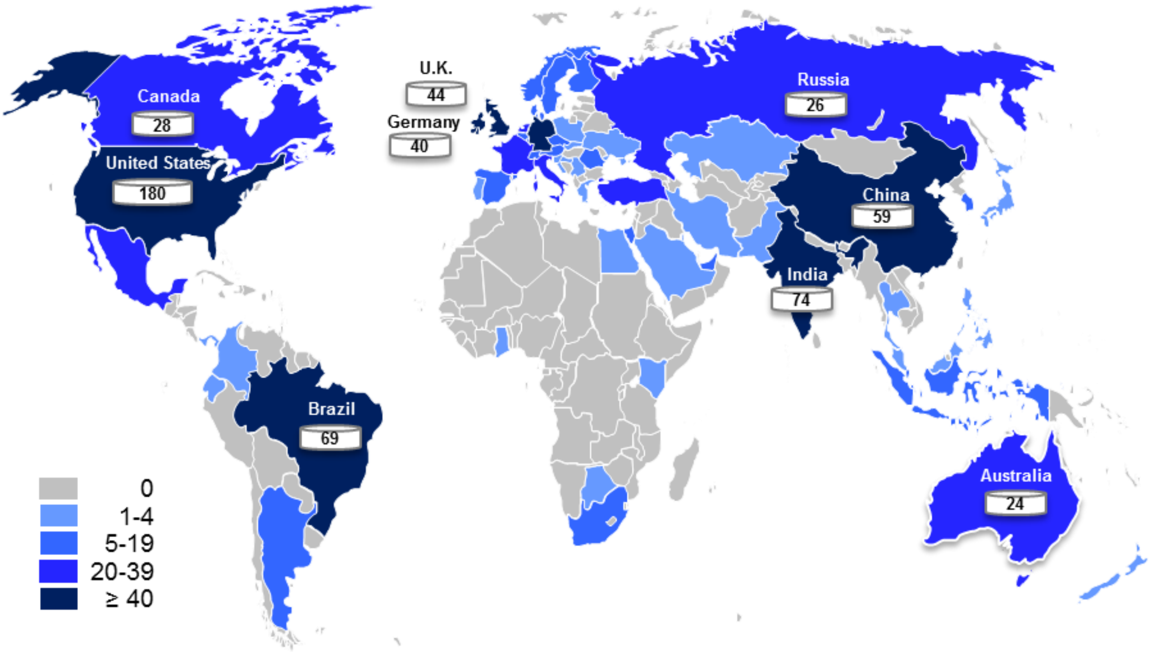


Figure 4-2 – Regional distribution of respondents of the questionnaire

The map shows that English-speaking countries are more strongly represented than other countries. However, for European countries and the big emerging countries good subsample sizes are achieved.

The whole sample of 920 respondents represents the target group regarding job positions, in which important decision-making takes place. The following paragraphs illustrate different demographic information which is based on results in Appendix J. Additionally the main focus regarding the sample is illustrated as part of the following paragraphs.

Considering the countries of origin, more than a third of the sample is residential in Europe (35%), whereas Asia (26%) and Northern America (23%) represent two other groups of geographical regions, as Table J-1 shows. The rest of the sample is from Latin America and the Caribbean, Africa and Oceania. Apart from the geographical region, the economic region also originates from the respondent's country of origin, as the following pie chart (Figure 4-3) illustrates.

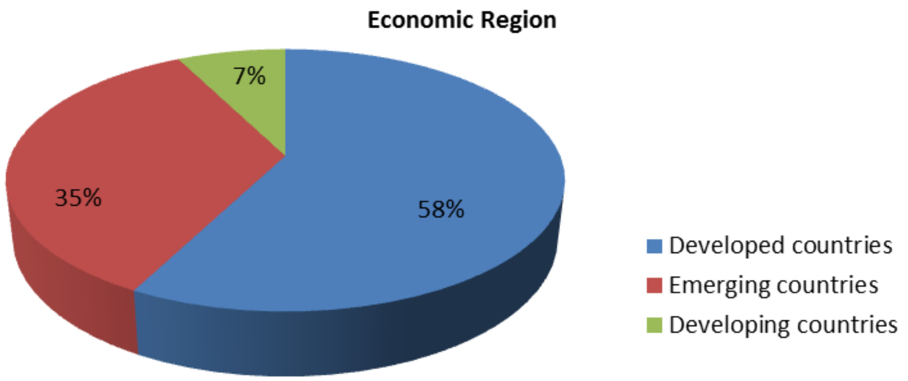


Figure 4-3 – Distribution of different economic regions

Table J-2 illustrates the distribution of the sample between developed, emerging and developing countries. More than half the sample (58%) consists of respondents from developed countries, such as the US (20%), United Kingdom (5%), Germany (4%) and Italy (4%). More than a third of the sample (35%) is from emerging countries (according to the BRIC[5] and N-11[6] classification), such as India (8%), Brazil (7.5%) and China (6%). The rest of the sample features developing countries (about 7% of the total).

Distinguishing between developed countries and emerging countries is another focus for the differences and patterns of diffusion of innovation barriers as part of this investigation based on its economic environment.

[5] BRIC is used as classification for emerging countries. BRIC considers Brazil, Russia, India and China as the new countries with very strong economies.
[6] N-11 is used as classification for emerging countries. Goldman Sachs extends the group of BRIC by the next eleven countries of strong economic power including countries such as Mexico, Indonesia and Nigeria (Wilson & Stupnytska, 2007).

The sample consists according to Table J-3 of respondents working in product management (30%), business development (22%), sales (23%) and marketing (17%). The rest works in general management (8%). Other job roles were eliminated. The following pie chart (Figure 4-4) a broad angle of organizational perspective with technology sales and marketing and according decision-making.

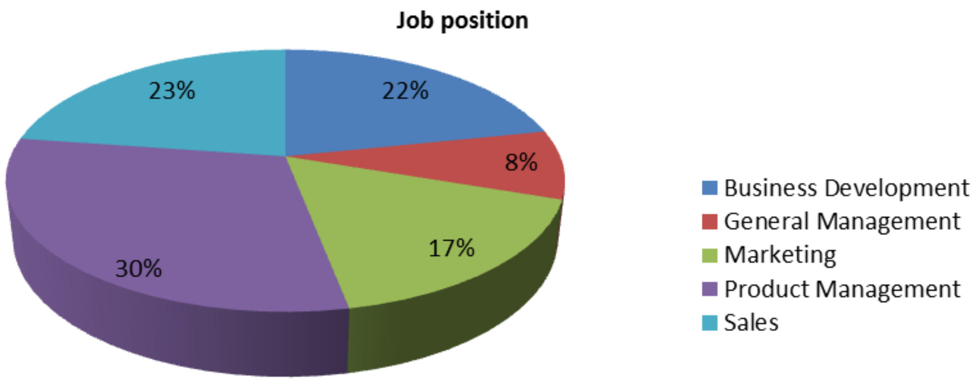


Figure 4-4 – Job positions of survey respondents

Regarding the size distribution of the companies, respondents work for, a majority (61%) of large companies (1000 employees or more) is found as Table J-4 shows. The rest of the sample is small and medium-sized enterprises (SME), of which 15% of the total are medium-sized companies (251–1000 employees) as the following figure (Figure 4-5) illustrates. Smaller companies than 10 or less employees were not considered within the survey.

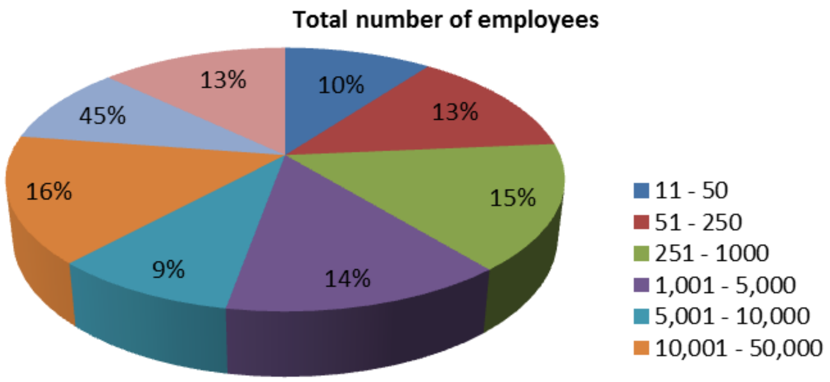


Figure 4-5 – Company size of survey respondents' employers

Most respondents (76%) as participants of the survey are between 30 and 50 years old (see Table J-5). A majority with an educational level of a Master´s degree or higher (59%) is found. Concerning the job experience, a majority has more than eight years of experience in their current job according to Table J-6. This high percentage shows that the sample represents a very experienced population which is important for good quality and validity. Most respondents (80%) have at least four years of experience in their current job role, as the following pie chart (Figure 4-6) shows.

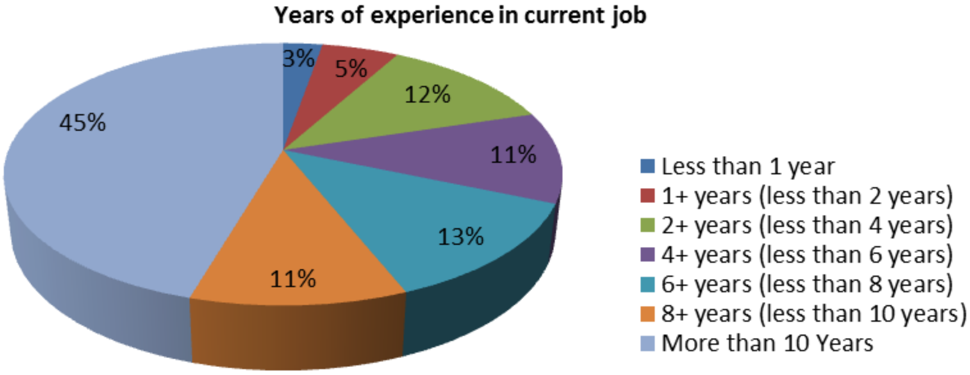


Figure 4-6 – Experience in current job of survey respondents

Apart from the experience, another important indicator is the frequency of dealing with innovation, as Table J-7 shows. Most of the participants work very frequently with evolutionary innovations. The respondents state to work less with revolutionary or even disruptive innovations, as the following bars (Figure 4-7) shows.

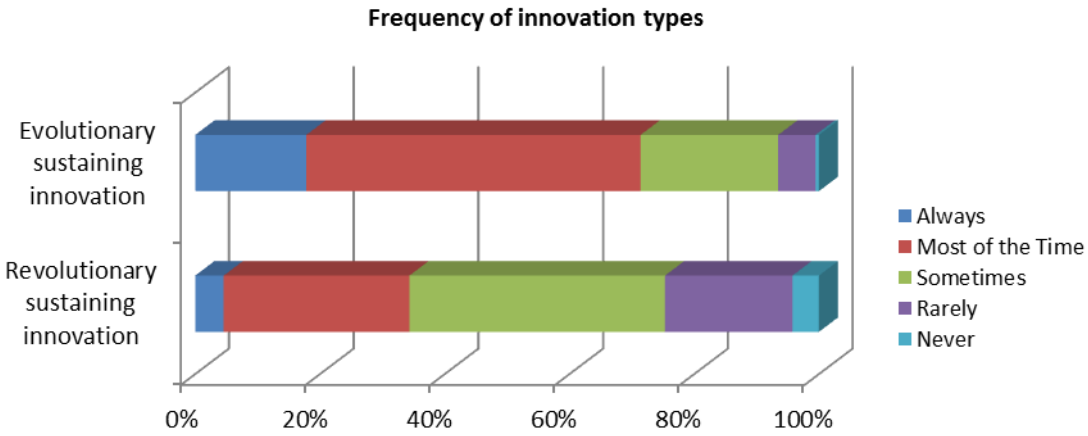


Figure 4-7 – Frequency of different types of sustaining innovation

The evaluation of the given statements describing different types of innovation evolves the frequency distribution of the bar chart. The frequency of dealing with disruptive innovation is comparable with the frequency of revolutionary sustaining innovation.

As the innovations can be products or technologies embedded in products, the respondents were asked about the type of good. According to Table J-8, more than two thirds of the respondents consider the good they are working with as industrial or investment good (67.5%). The rest, approximately one third, is working with consumer goods in B2C businesses.

From the industry segments as part of the survey, an illustration is given for the frequency of technology-intensive industries according to NACE[7] classifications. According to Table J-9, a small portion of the sample features low and medium-low technology companies (15% of the total), operating in industries such as oil and energy, consumer goods, or food and beverages, as the following diagram (Figure 4-8) represents.

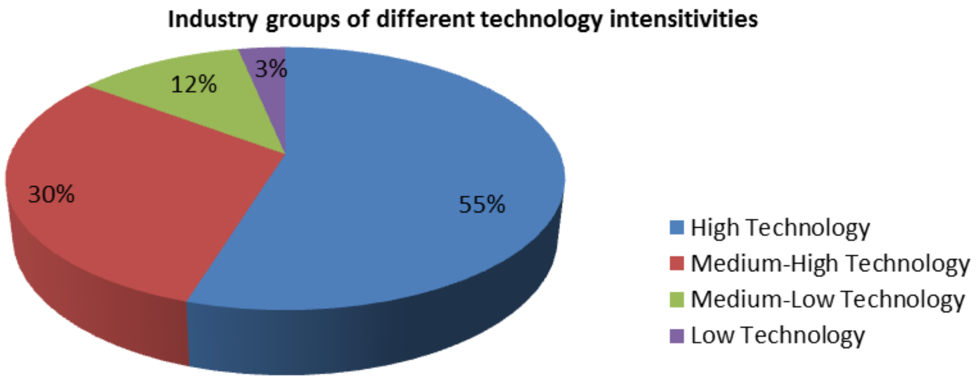


Figure 4-8 – Distribution of industries with different levels of technology intensity

[7] NACE is used as 'statistical classification of economic activities in the European Community'. The industries are classified as manufacturing high- or medium high-tech industries according to their technological intensity on their global level regarding to NACE Revision 2 (Eurostat, 2011).

Almost a third of the sample consists of respondents working in medium high-technology companies, operating in sectors such as automotive (12%), electrical manufacturing (8%) and chemicals (7%) according to Table J-10.

More than half of the sample consists of respondents working in high-technology companies, operating in sectors such as medical devices industry (13%), telecommunication (11%), IT (8%) and pharmaceuticals and biotech (6%), as the following pie-bar chart (Figure 4-9) illustrates.

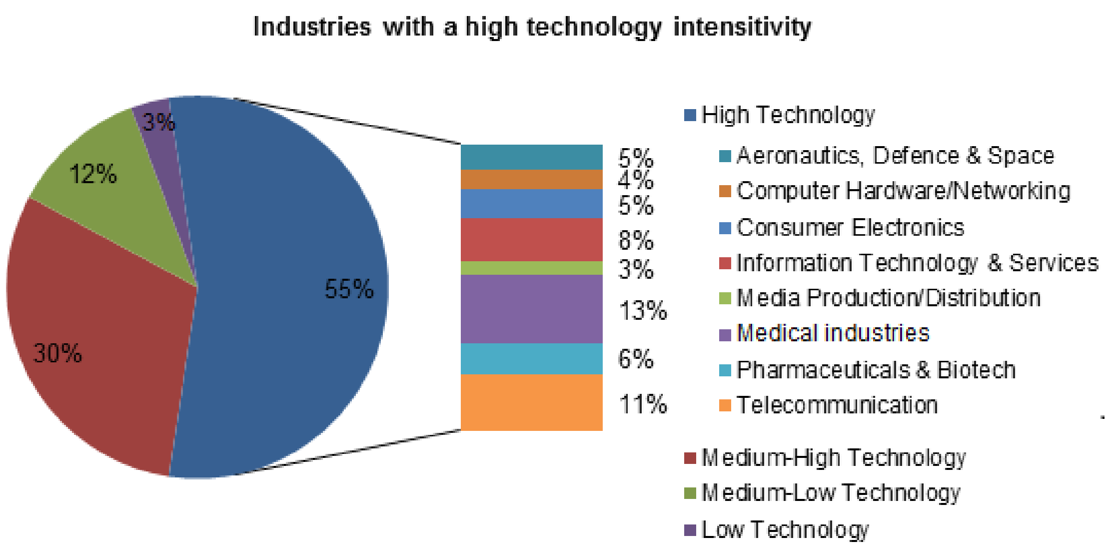


Figure 4-9 – Distribution of industries with a high level of technology intensity

The sample representing industries considered as high-technology and medium high-technology companies (85% of the total) are the main focus of this research regarding differences of diffusion barriers based on its industrial environment. In absolute numbers some of these industries are quite strongly represented with more than 40 participants, whereas other industries are poorly represented, as the following figure (Figure 4-10) illustrates.

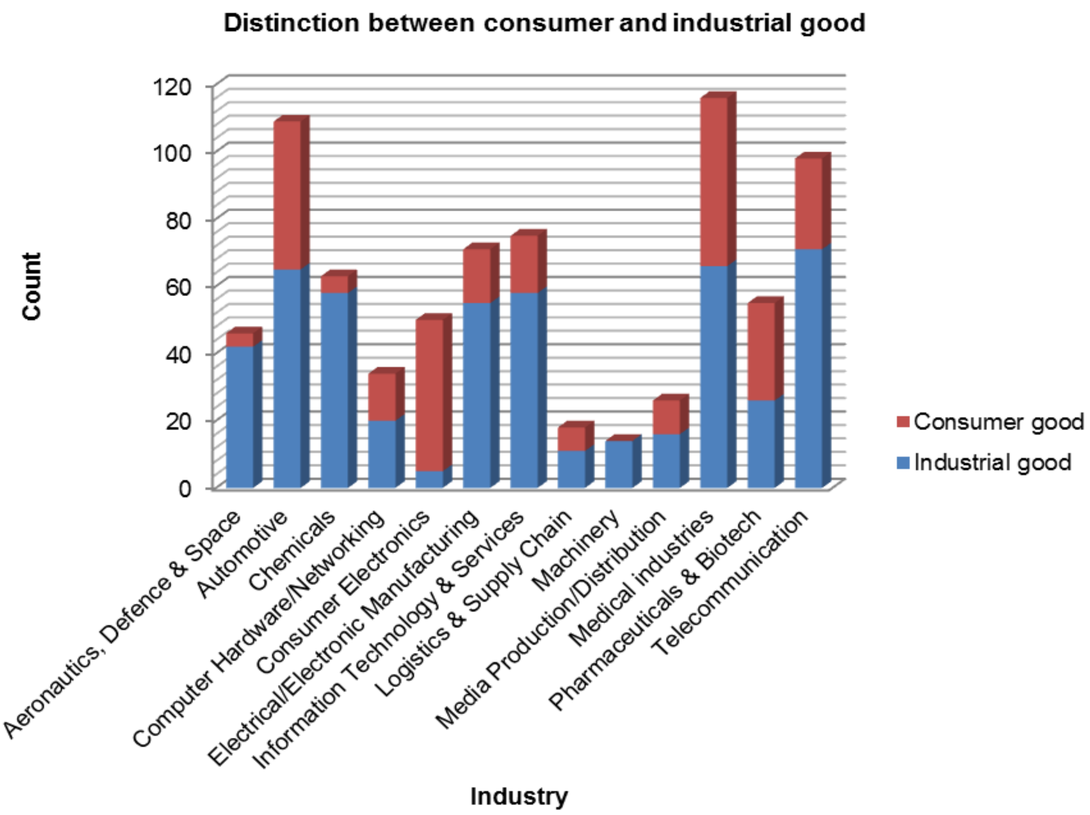


Figure 4-10 – Frequency of industrial and consumer goods (technology-intensive)

Figure 4-10 also demonstrates the distribution of industrial and consumer goods within technology-intensive industries. According to Table J-11, the industries of aeronautics, chemicals, electric/electronic manufacturing, IT and telecommunication represent industries with responses dominated by industrial goods. Consumer electronics clearly represents B2C business. The subgroups of automotive and medical industries consist of both, respondents working in B2B and in B2C.

The main focus of the research is on the sample representing industries considered as high- and medium high-technology, located in either industrialised or emerging countries. This sample adds up to a number of 726 participants. Different types of good, economic regions and industries can show variations and different patterns of importance for diffusion barriers. An initial analysis is performed with tendencies showing the extent of agreement to the relevance of the barrier items in the perception of the participants of the survey. As practitioners should benefit from the results, the following tendency tests contribute essentially to the provision of a usable framework.

4.2.3 Tests of central tendencies

4.2.3.1 Tendencies of the sample with high technology-intensity

For ordinal data, instead of mean values, central tendency tests are performed. Field (2005), Saunders et al. (2007) and Zikmund et al. (2013) recommend applying the mode and median value when assessing the trend of ordinal survey data.

An initial evaluation of tendencies among the different statements for barrier items of the whole sample of 920 respondents shows variations according to Table K-1. A ranking of agreement regarding the importance of barriers can be established based on its mode and median values. Some barrier items show relatively small values for mode and median, which represents agreement with their importance in the perception of the participants, whereas others show higher values, which represents disagreement.

As the title of the research shows, an approach of generalization for technology-intensive industries is followed. Therefore, this test focuses on high-tech and medium-high tech industries of developed and emerging countries with a sample size of 726 respondents. According to Table K-2 and Figure 4-11, the result shows a certain variation among the barrier items.

<u>Barrier items</u>

Some barrier items show disagreement in the perception of the respondents. Five Likert-type items represented show the highest values for mode, showing a level of disagreement on the statement as Table 4-5 shows.

Variable name	Statement short form	Disagreement
T_Utlty_IC	Utility perceived to be less than o.T.	Strong
T_Adptb_C	n.T. not adaptable to community needs	Strong
T_Utlty_M	n.T. fails to exceed measurable specifications of o.T.	considerable
S_Cntxt_M	Access is granted to small social groups	considerable
S_Orntn_I	Personal orientations towards its use are negative.	considerable

Table 4-5 – Disagreed barriers (mode, medium) for technology-intensive industries

The according values for median and skewness support these results as well. A distinction between considerable and strong disagreement is made depending on their median value.

In contrast to that, the two barrier items T_Cmplx_M and S_Cntgn_M show the lowest values for mode, and therefore strong agreement on the statement. Most barrier items show the value of 3 for its mode. Those items, whose mode and median equals 3 are considered as showing considerable agreement, listed in Table 4-6.

Variable name	Statement short form	Agreement
T_Cmplx_M	Complex radically n.T. cannot be introduced frequently	strong
S_Cntgn_M	Poor execution of marketing	strong
T_Cmplx_IC	Complexity focuses attention on overall effectiveness	considerable
T_Cmplm_IC	Complementarity of o.T. results in higher total utility	considerable
T_Cmplm_M	No dominant design within an industry compared to o.T.	considerable
S_Cntxt_I	Individuals face difficulties in accessing n.T.	considerable
S_Orntn_C	Community of users is towards o.T.	considerable
S_Cntgn_IC	Contagion not strong enough to displace community norms	considerable
S_EnvAw_C	Sustainability aspects of n.T. not explained to community	considerable
S_EnvAw_M	Marketing exaggerates environmentally friendliness	considerable
L_Cpcty_C	Not enough resource to access training	considerable
L_Cpcty_M	Not sufficient resources & guidance for learning n.T.	considerable
L_Cpblt_M	No possibilities for experiencing n.T. in industry	considerable
L_CstLrn_IC	High switching costs and learning efforts	considerable
L_CstLrn_M	Learning efforts within industry are expensive.	considerable

Table 4-6 – Agreed barriers (mode, medium) for technology-intensive industries

Table 4-6 shows that quite a lot of barrier items are agreed on. While two barrier items show a strong agreement, over a dozen barrier items only show a considerable agreement.

While two of the newly introduced barrier items show considerable agreement, all others are evaluated as neutral or even disagreed with (T_Adptb_C). Figure 4-11 shows the variations among all barrier items for technology-intensive industries.

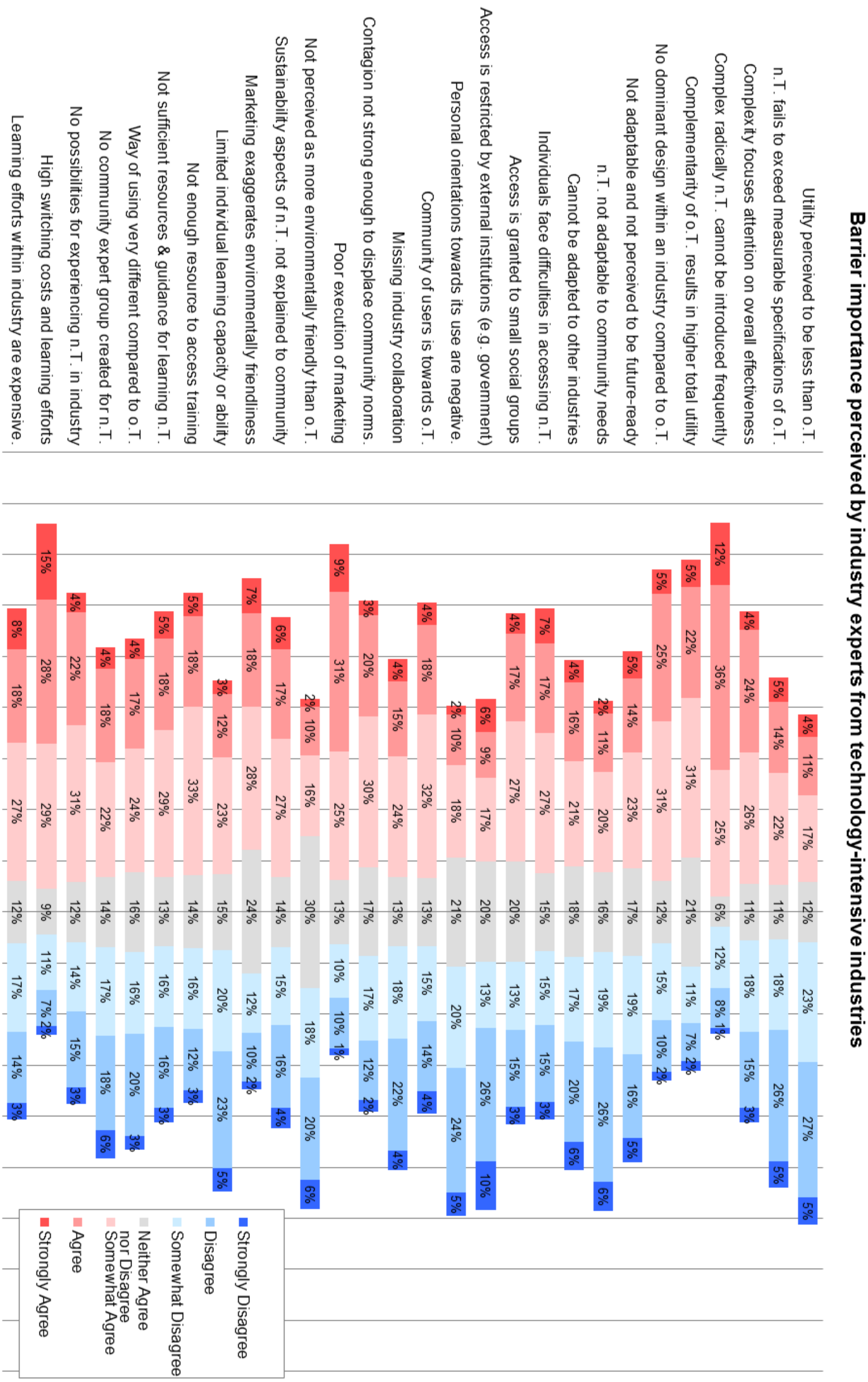


Figure 4-11 – Agreement frequencies for barriers in technology-intensive industries

<u>*Barrier variables*</u>

Referring to the barrier variables, the focus should rather be on the median value as multiple modes can exist (see Table K-3). The variable of technological *complexity* (T_Cmplx) shows the smallest value for its mode and its median value, which represents agreement. The variables for technological *complementarity* (T_Cmplm), *costs of learning* (L_CstLrn) and social *contagion* (S_Cntgn) also show low values (smaller or equal to 3.5) concerning its median. Technological *utility* (T_Utlty) shows the highest values for its median (bigger or equal to 4.5), which represent disagreement. The following diverging stacked bar chart of Figure 4-12 supports this.

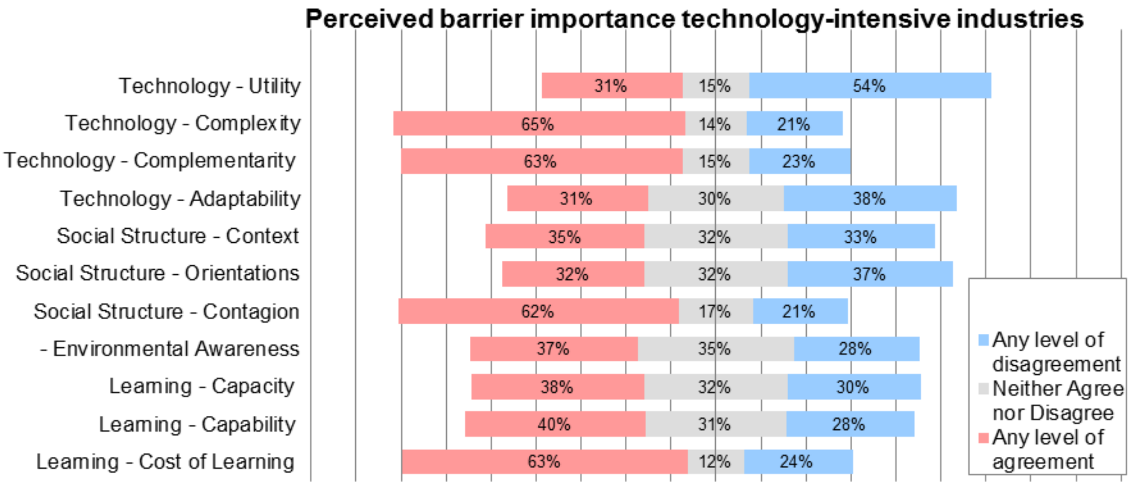


Figure 4-12 – Frequency of variable agreements of technology-intensive industries

With tests of central tendencies on the whole sample and focusing on those with high and medium-high technology-intensity, further tests are conducted regarding selected high-tech and medium high-tech industries.

4.2.3.2 Tendencies of selected high-tech and medium high-tech industries

Variations among the barrier items and barrier variables are presented in the previous section. As practitioners of a specific industry may want to focus on the dominating barriers in their industry, according tendencies are researched. Similarly, mode and median values are focused on according to suggestions from literature regarding ordinal data (Field, 2005; Saunders et al., 2007; Zikmund et al., 2013).

The existence of variations is presented in the section 4.2.4.4 between industrial and consumer goods and different industries. The tests of central tendencies and their variation among barriers are performed on high-tech industries. Other tests are on variations among industries and goods and are explained in section 4.2.4.3.

Tests are performed with subgroups that are categorized as high or medium high-technology intensive industries. With the existence of variation regarding the type of good, industry subgroups that constitute of similar proportions of participants working with industrial goods and consumer goods are analysed additionally concerning their type of goods. In section 4.2.2 it is shown (see Figure 4-10) that some industry samples consist of participants mainly working with one type of good (either in B2B or in B2C), whereas the subgroups of medical and automotive industries represent both, B2B and B2C businesses. Therefore, the following table (Table 4-7) shows subgroups, whose sample size is at least 40 sets of answers, are considered:

Industry	Consideration	Sample size
Aeronautics, Defence & Space	Complete sample of industry	46
Automotive	Complete sample of industry (B2B and B2C)	**109**
	Distinguished subgroup of industrial goods	65
	Distinguished subgroup of consumer goods	44
Chemicals	Complete sample of industry	63
Consumer Electronics	Complete sample of industry	50
Electrical/Electronic Manufacturing	Complete sample of industry	71
Information Technology & Services	Complete sample of industry	75
Medical industries	Complete sample of industry (B2B and B2C)	**116**
	Distinguished subgroup of industrial goods	66
	Distinguished subgroup of consumer goods	50
Pharmaceuticals & biotech	Complete sample of industry	55
Telecommunication	Complete sample of industry	98

Table 4-7 – Subgroups of industries taken into consideration for barrier variations

This size seems to be sufficiently big to draw generalizations and to prepare tailored frameworks for practitioners. For the automotive and medical industry, both the industry sample and the subordinate samples differentiated by the type of good are considered.

Barrier items

The tendencies among the different statements of barrier items show a variation of their existence and importance within each industry according to tables of Appendix K (see Table K-4 to Table K-16).

A ranking of agreement can be established based on its mode and median values. Depending on the industry and the type of good, some barrier items show relatively small values for mode and median, which represents a certain agreement of its existence and importance in the perception of the participants, whereas others show higher values, which represents a certain disagreement.

Additionally the frequencies of the agreement levels in the perception of survey participants support the results for central tendencies regarding the different high-tech industries, applying diverging stacked bar charts (Heiberger & Robbins, 2014) as illustrations (see Figure Q-1 to Figure Q-9). Additional diverging stacked bar charts as frequency illustrations of the data from the automotive industry (see Figure Q-10 and Figure Q-11) and the industry of medical devices (see Figure Q-12 and Figure Q-13) are used to discriminate between the types of good for B2C and B2B businesses.

The illustration of the frequencies of agreement levels with barrier items for each industrial context provides illustrative weighting information regarding the importance and existence of diffusion barriers.

Barrier variables

Referring to the barrier variables and focussing mainly on the median, Appendix K (see Table K-17 to Table K-29) also shows differences in the results of the different industries as the following graphics (see Figure 4-13 to Figure 4-21) illustrate.

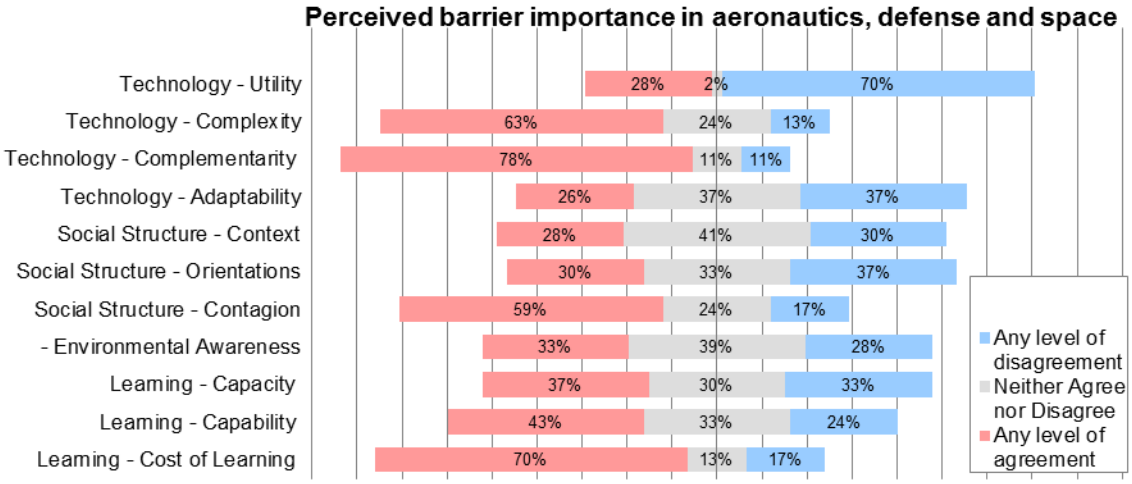


Figure 4-13 – Agreement frequencies for barrier variables in aeronautics

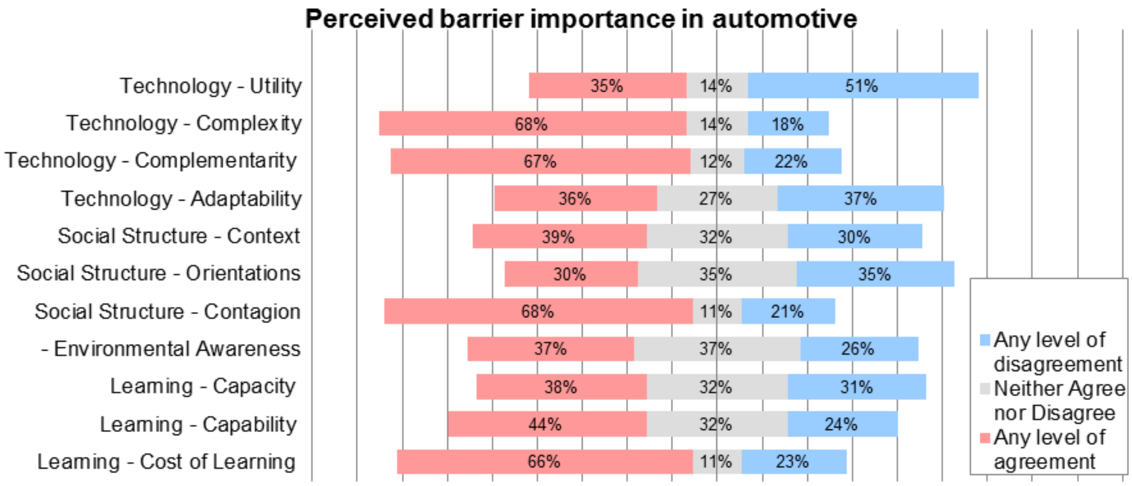


Figure 4-14 – Agreement frequencies for barrier variables in automotive

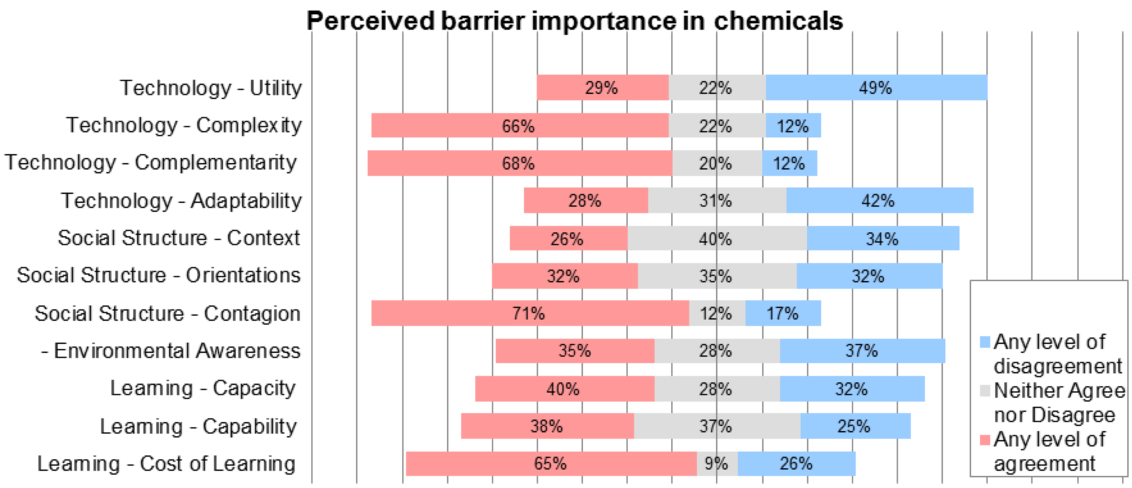


Figure 4-15 – Agreement frequencies for barrier variables in chemical industry

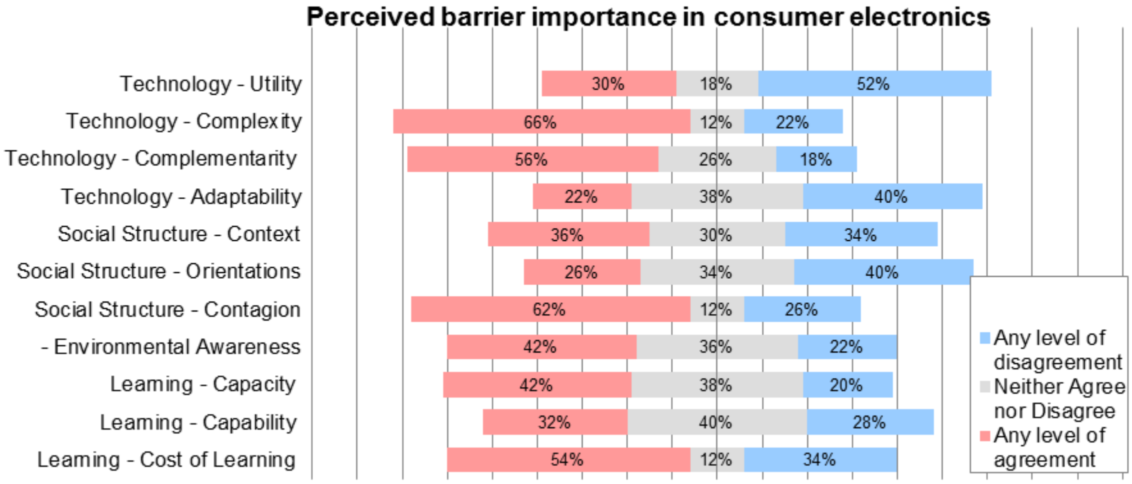


Figure 4-16 – Agreement frequencies for barrier variables in cons. electronics

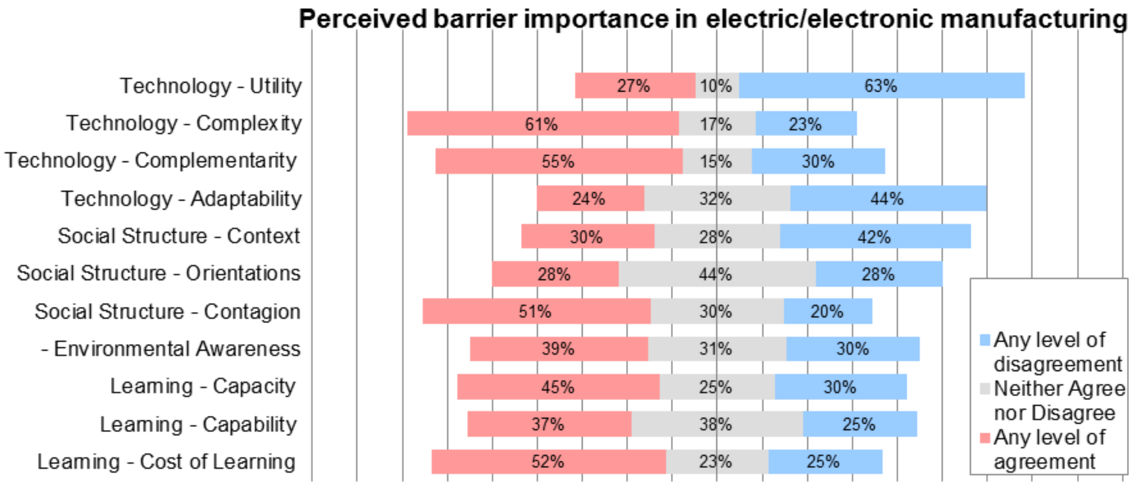


Figure 4-17 – Agreement frequencies for barrier variables in electr. manufact.

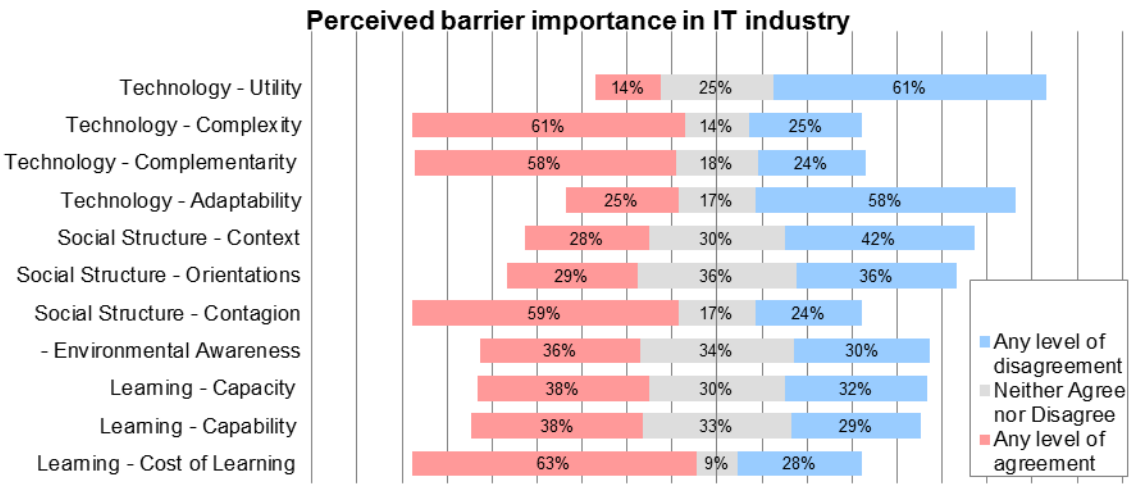


Figure 4-18 – Agreement frequencies for barrier variables in IT industries

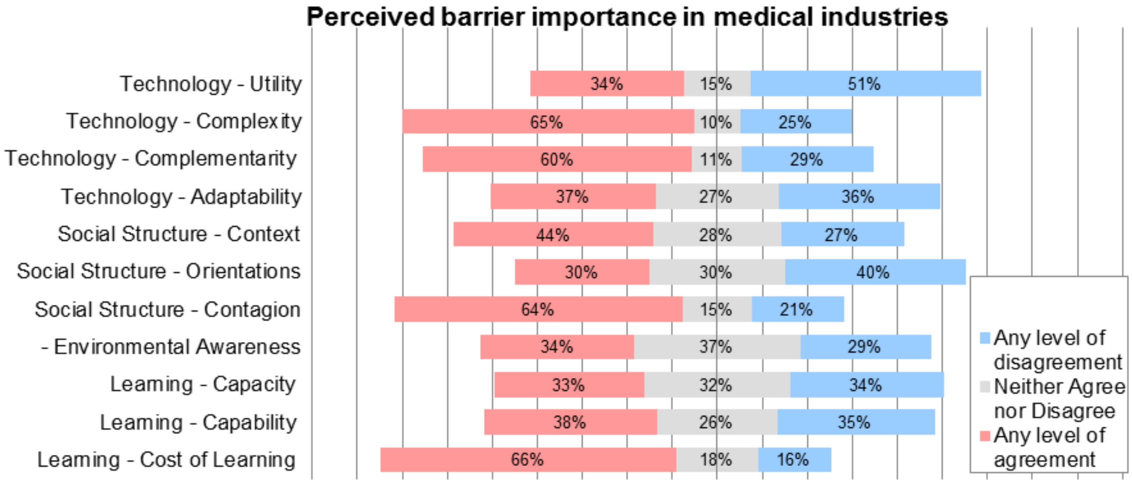


Figure 4-19 – Agreement frequencies for barrier variables in medical industries

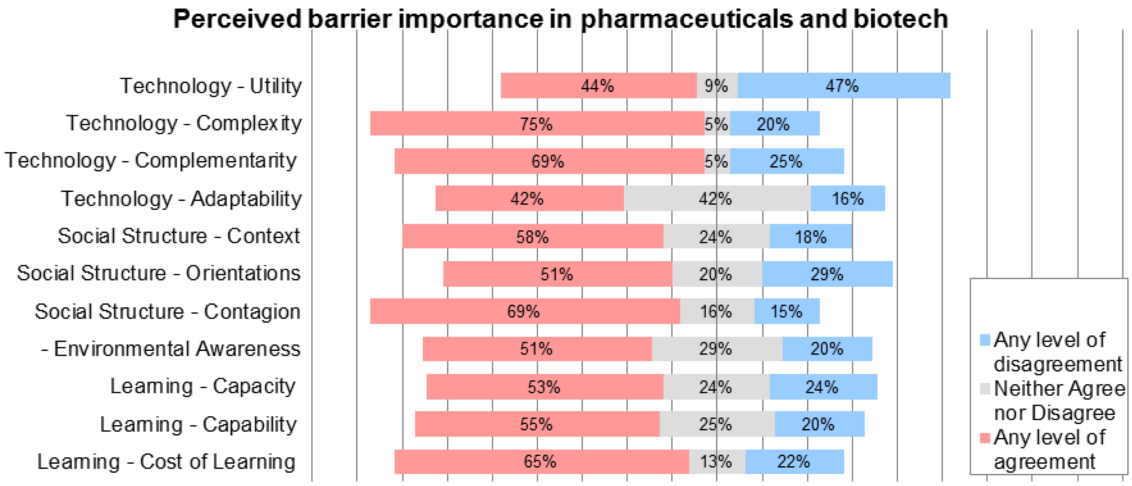


Figure 4-20 – Agreement frequencies for barrier variables in pharma and biotech

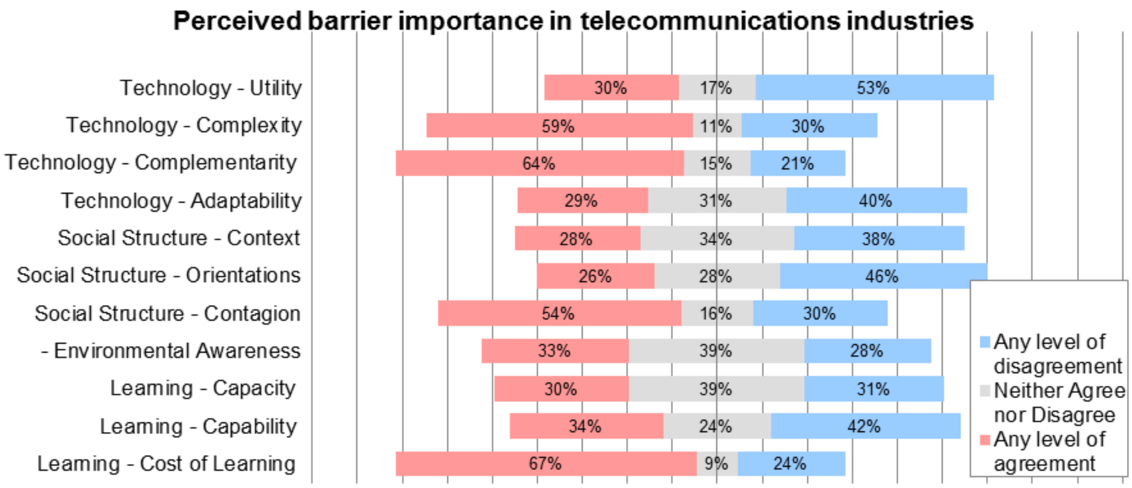


Figure 4-21 – Agreement frequencies for barrier variables in telecommunication

4.2.3.3 Summary of tendency tests

Both, the results of central tendencies of the whole sample of focus, representing all technology-intensive industries, as well as the results for each industrial context, show varations among barriers. Among the barrier items and among the barrier variables, the perceived importance and relevance varies. Some barriers seem to be more important than others.

For the exploratory approach of this study, illustrations of frequencies (see section 4.2.3.1) are used in addition to statistics of central tendencies as Saunders et al. (2007) suggest. Assuming the Likert-type items and scales to be ordinal data, the frequency illustrations introduced in section 4.2.3.2 are used to support the presentation of results as a part of the next sections.

With an initial idea on the tendencies of the importance and respectively the relevance of the different barrier items (Likert-type items) and barrier variables (Likert-type scales), variations across the barriers are shown. However, differences and variations are also tested between independent subgroups. The results are described in the following section.

4.2.4 Variations of barrier items and variables

4.2.4.1 Testing variations among respondents and justification of applied tests

The formed hypothesis H1 questions whether variations exist among the diffusion barriers (see section 3.2.3). To test the hypothesis several subordinate tests are performed. The hypothesis is tested regarding different criteria as part of the next sections. Each test is based on subordinate hypotheses and according null hypotheses.

Considering the trade-off regarding benefits of different analysis methods (see section 3.4.5.1), the advantages of non-parametric techniques (Kothari, 2004) suite better to achieve the research objectives. A further aspect is data distribution. Whether ordinal data is normally distributed can be tested via Kolmogorov-Smirnov (Field, 2005; Saunders et al., 2007). As barrier items and variables are not normally distributed (see Table L-1 and Table L-2), differences are tested via non-parametric tests (Townsend & Ashby, 1984; Clegg, 1998). As Kuzon et al. (1996) and Field (2005) recommend for ordinal data, the non-parametric methods of Mann-Whitney for two independent groups and of Kruskal-Wallis for more than two groups to assess differences were applied. With a significance level of $\alpha = .05$ for these two-tailed tests, the null hypotheses that there are no differences can be rejected with a probability smaller than the α-level.

Very different criteria can be used for the tests. The examples for variation tests with different job positions (see Table M-1), educational background (see Table M-2) and depending on the company size (see Table M-3) show that there is almost no significant variation as almost all α-values are higher than .05 (see tables from Appendix L).

As one of the objectives is to provide a framework for practitioners, the investigation of interesting criteria for practitioners is focused on in testing variations. The following sections describe the performed tests with the criteria of economic region, type of good and type of industry.

4.2.4.2 Variations due to different economic regions

The ordinal barrier items and variables as the dependant variables are tested on two independent samples from developed and emerging countries by the method of Mann-Whitney as suggested by Kuzon et al. (1996), Kothari (2004) and Field (2005). The following hypotheses apply for each Likert-type item and scale of the test sequence:

H1_h1-0: ***µ (developed countries)*** **=** ***µ (emerging countries)***

H1_h1-1: ***µ (developed countries)*** **≠** ***µ (emerging countries)***

Barrier items

All statements of barrier items represented by Likert-type items were tested and show, referring to Table M-4, significant differences. The following barrier items (see Table 4-8) show differences at a significance-level smaller than .05:

Item name	Statement short form	LF-model origin
T_Cmplx_M	Complex radically n.T. cannot be introduced frequently	Yes
S_Cntxt_I	Individuals face difficulties in accessing n.T.	Yes
S_Cntxt_C	Access is granted to small social groups	Yes
S_Cntxt_M	Access is restricted by external institutions (e.g. government)	Yes
S_Cntgn_M	Poor execution of marketing	Yes
S_EnvAw_C	Sustainability aspects of n.T. not explained to community	No
S_EnvAw_M	Marketing exaggerates environmentally friendliness	No
L_Cpcty_I	Limited individual learning capacity or ability	Yes
L_Cpcty_C	Not enough resource to access training	Yes
L_CstLrn_IC	High switching costs and learning efforts	Yes

Table 4-8 – Barrier item with significant differences between economic regions

According to the frequencies of agreement (compare Figure M-1 and Figure M-2) for all barrier items listed, respondents from emerging regions provided more agreement on the importance and relevance.

The additional comparison of the frequencies between the listed Likert-type items and the variable of economic regions, allows a more profound evaluation of the results (Fields, 2005; Saunders et al., 2007). The following examples only describe those barrier items which are clearly differing in summing up any levels of agreement.

One example chosen presents the crosstabs of economic region and the perception of the barrier item S_EnvAw_C. Differences are illustrated by the following graphic.

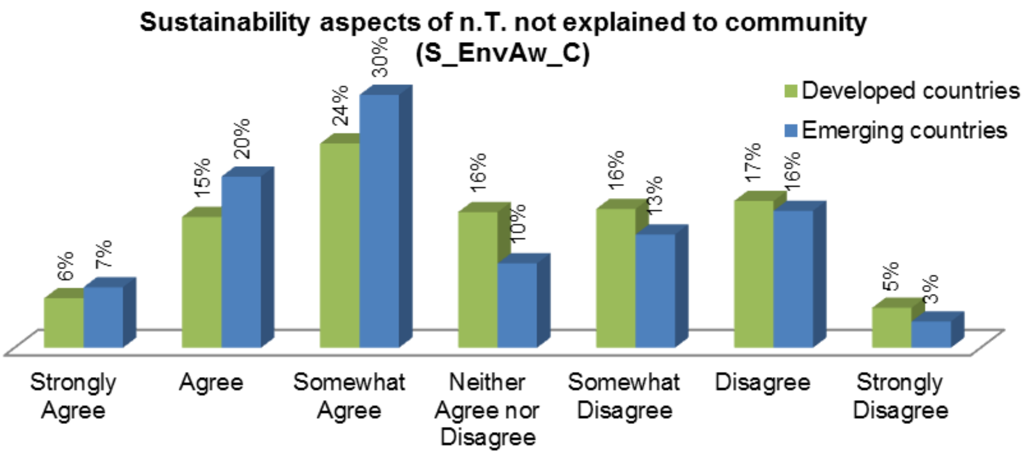


Figure 4-22 – Differences of sustainability information regarding economic region

As Figure 4-22 shows, significantly larger proportion of participants of emerging countries (57%) agrees on the importance and relevance of this diffusion barrier compared with 45% of developed countries.

The second example chosen is the examination, if there was a relationship between economic regions and the perception of the barrier item S_Cntxt_I (‘Individuals face difficulties in accessing n.T.’). A significantly larger proportion of participants of emerging countries (64%) agrees on the barrier compared with 46% of developed countries. Similar results can be presented for the other barrier items regarding *social context* and access to technology (S_Cntxt_C and S_Cntxt_M), as the following crosstab illustration (Figure 4-23) shows.

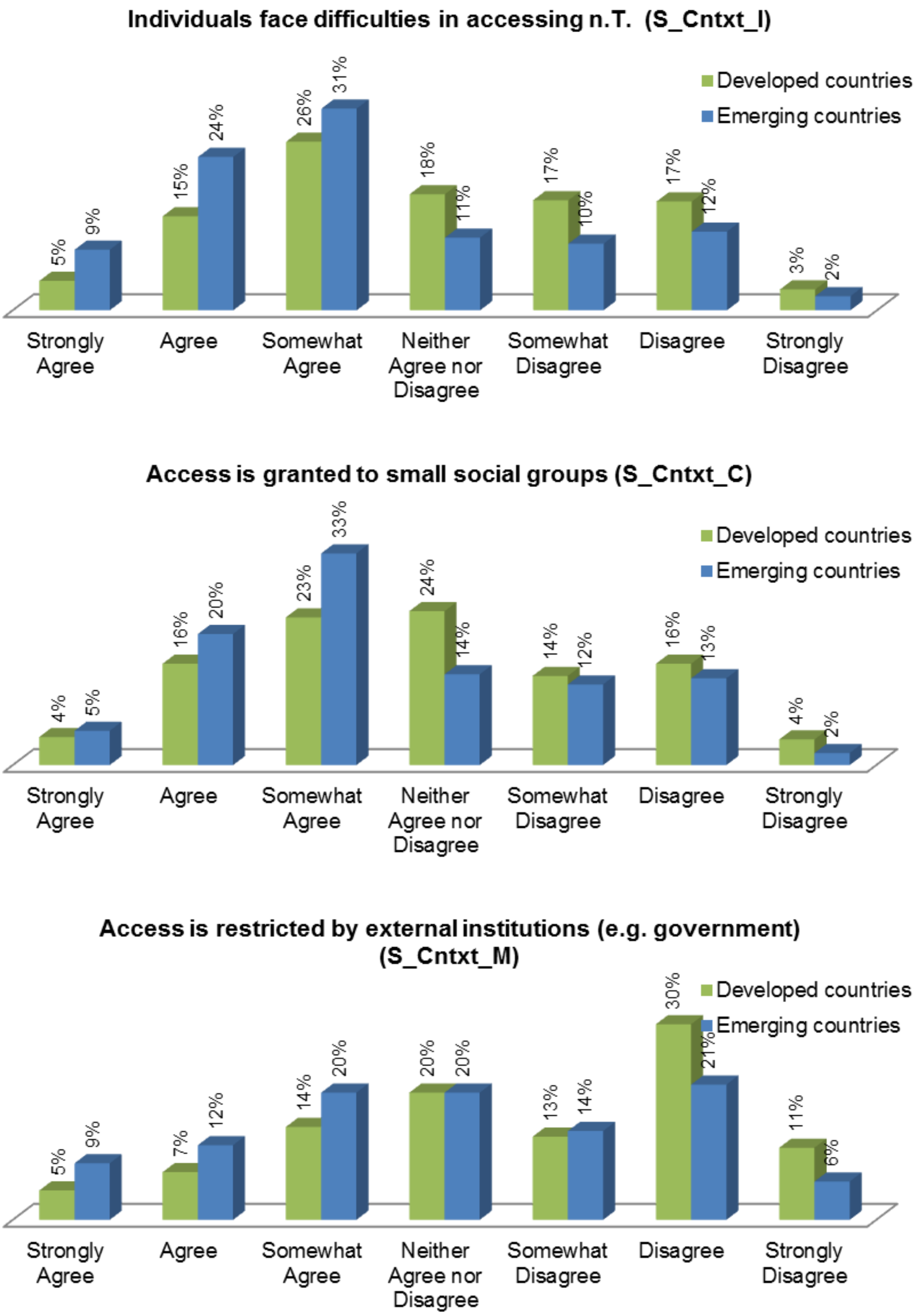


Figure 4-23 – Differences of context/access aspects regarding economic region

In comparison to the summed up agreement of participants from developed countries, the respondents of emerging countries show a much higher agreement on the existence and importance of diffusion barriers regarding their frequency of responses.

A further example is for the two economic regions and the perception of the barrier item L_Cpcty_I. The following graphic (Figure 4-24) shows significantly larger proportion of participants from emerging countries (46%) agreeing on the barrier compared with 34% of developed countries.

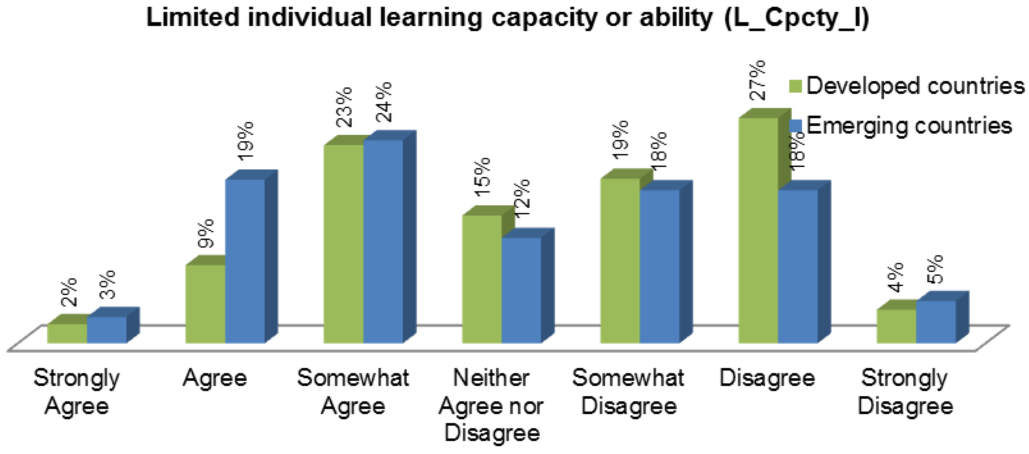


Figure 4-24 – Difference of individual learning capability regarding economic region

Similar results show the crosstabs of economic region and the perception of barrier item L_Cpcty_C. The following graphic (Figure 4-25) shows this by a stronger agreement of participants from emerging countries (64%) agreeing on the barrier compared with 52% of developed countries.

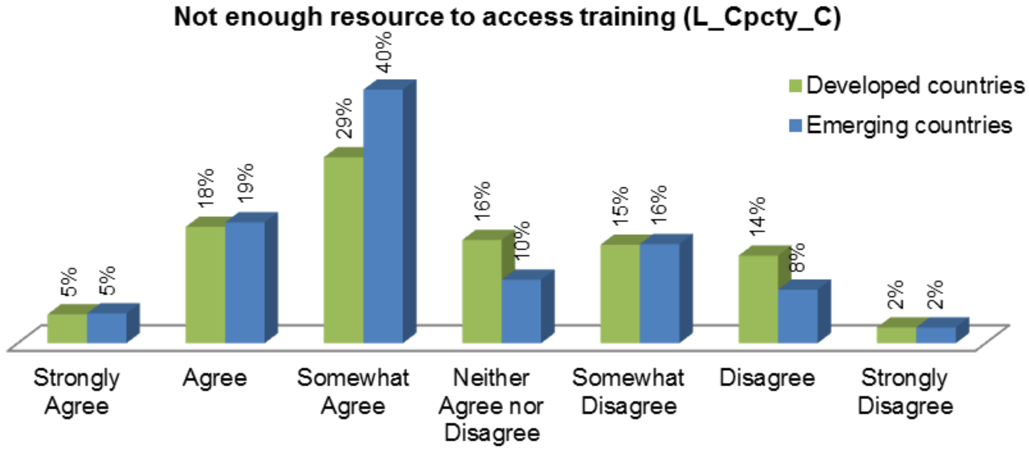


Figure 4-25 – Differences of resources for training regarding economic region

The described test results illustrate variations among barrier items. As the barrier items form the barrier variables, additional tests were performed. All barrier variables were tested on significant differences between the two economic regions.

Barrier variables

All barrier variables represented by Likert-type scales were tested and show, referring to Table M-5, significant differences between developed and emerging countries. The following table (Table 4-9) shows barrier variables show differences at a significance-level smaller than .05:

Variable name	Description	LF-model origin
T_Adptb	Technology – *adaptability*	No
S_Cntxt	Social structure – *social context*	Yes
S_EnvAw	Social structure - *environment awareness*	No
L_Cpcty	Learning – *learning capacity*	Yes

Table 4-9 – Barrier variables with significant differences between economic regions

For the listed barrier variables, the results of correlation tests with the variable of economic regions representing the degree of industrialization are described. Assuming equidistant scales, correlation tests with Spearman´s ρ were conducted for all barrier variables showing significant differences at a level smaller than .05. With a comparison of the frequencies of the barrier variables and the two economic regions, results can be outlined as follows.

In addition to the tests on significant variations and a suitable illustration, the comparison of tendency statistics (compare Table M-6 and Table M-7) support the evaluation. The following illustration allows the comparison of frequencies of agreements between developed and emerging countries.

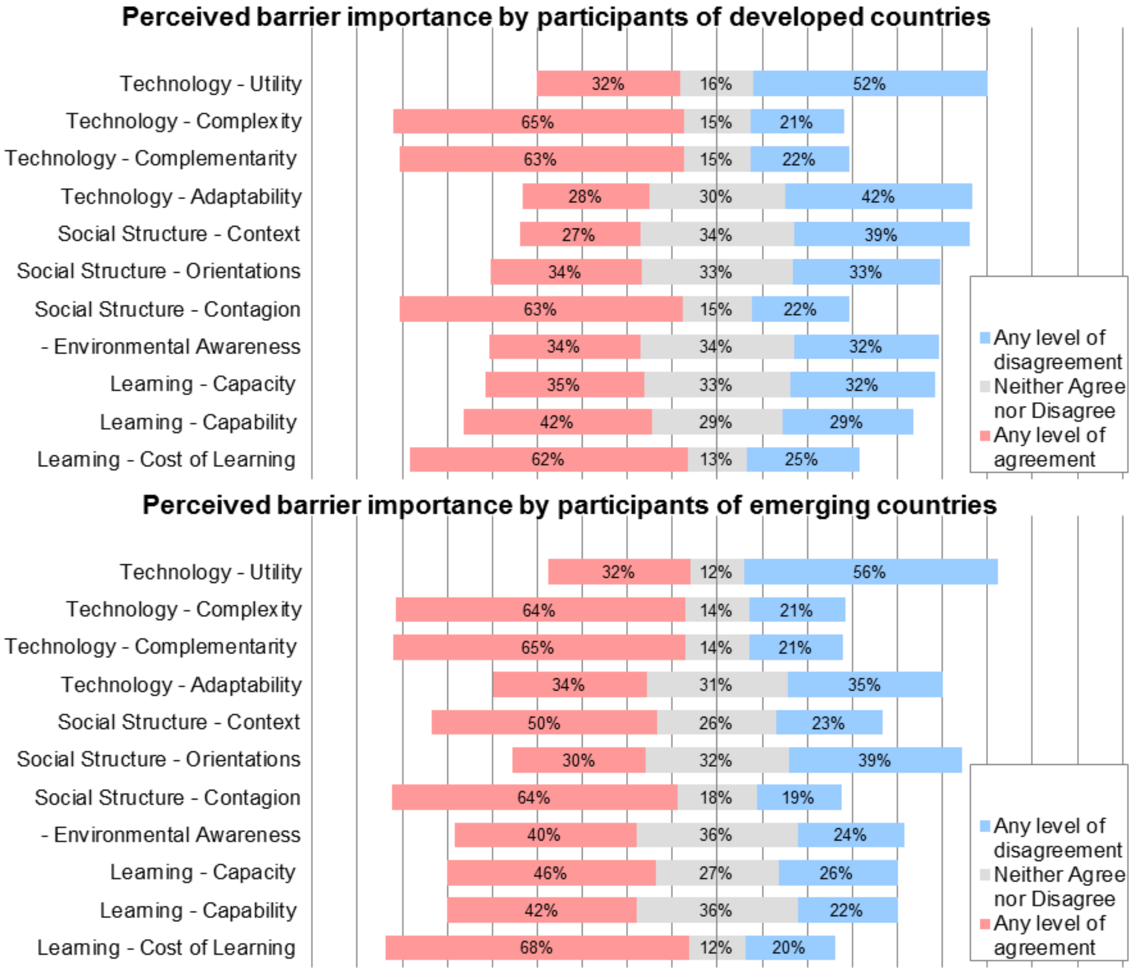


Figure 4-26 – Frequencies of agreement with barrier variables for economic regions

As Figure 4-26 shows, a significantly larger proportion of participants of emerging countries (34%) agrees on the barrier variable of technological *adaptability* (T_Adptb) and only 28% of the participants of developed countries agreed. Similarly, a larger proportion of participants of emerging countries (40%) agrees on the barrier variable *social context* (S_Cntxt) compared with <27% of developed countries. Also, for a significantly larger proportion of participants of emerging countries (40%) the barrier variable of the *environmental awareness* (S_EnvAw) is evaluated as being relevant. In addition, the figure also shows that the barrier variable of the *learning capacity* (L_Cpcty) is as well perceived as relevant by a higher proportion of participants from emerging (47%) than from developed countries (<36%). The comparison of Table M-6 with Table M-7 also shows that the barrier variables T_Adptb, S_Cntxt, S_EnvAw and L_Cpcty show significant differences between developed and emerging regions.

The results reveal significant relationships between the variable of economic regions and the four barrier variables ($p < .05$), as Table M-8 shows. The correlation tests with Spearman's Rho show correlations with negative coefficients but the strength is very weak (S_Cntxt) or extremely weak (T_Adptb, S_EnvAw and L_Cpcty). Thus, a significant negative correlation can be described for the barrier variables. Respondents from emerging economic regions evaluate the barrier variables as being more important than respondents from advanced economies.

4.2.4.3 Variations due to different industries

As the objective of the research is on high-tech industries, tests are performed with industry subgroups that are categorised as high and medium high-technology intensive and whose sample size is at least 40 sets of answers. This size seems to be sufficiently large to draw generalizations.

As more than two independent subgroups are analysed with ordinal, not normally-distributed data, the non-parametric method of Kruskal-Wallis was applied (see section 3.4.5.4) as suggested by Kuzon et al. (1996), Kothari (2004) and Field (2005).

Barrier items and barrier variables as the dependant variables are tested on the independent samples of the industries of automotive, chemicals, consumer electronics, electronic manufacturing, IT, medical, pharmaceutics & biotechnology and telecommunication, not considering their origin of developed and emerging countries.

The following hypotheses apply for each barrier item and barrier variable of the test sequence regarding differences over the industries represented by industry X and industry Y:

H1_h2-0: μ *(industry X)* $=$ μ *(industry Y)*

H1_h2-1: μ *(industry X)* $\neq$ μ *(industry Y)*

The following paragraphs distinguish between barrier items and barrier variables.

Barrier items

All barrier item statements were tested. Referring to Table M-9, various barrier items show significant differences. The following barrier items (see Table 4-10) show differences at a significance-level smaller than .05:

Item name	Statement short form	LF-model origin
T_Cmplm_M	No dominant design within an industry compared to o.T.	Yes
T_Adptb_M	Cannot be adapted to other industries	No
S_Cntxt_I	Individuals face difficulties in accessing n.T.	Yes
S_Cntxt_C	Access is granted to small social groups	Yes
S_Cntxt_M	Access is restricted by external institutions (e.g. government)	Yes
S_Orntn_C1	Community of users is towards o.T.	Yes
S_Cntgn_IC	Contagion not strong enough to displace community norms.	Yes
S_EnvAw_I	Not perceived as more environmentally friendly than o.T.	No

Table 4-10 – Barrier items with significant differences for high-tech industries

Cross tabulation allows insights into the frequencies of levels of agreement between the listed Likert-type items and the variable of industries. Therefore, illustrations of frequency (see Figure Q-1 to Figure Q-9) support the analysis (Saunders et al., 2007).

One example chosen is the examination of the cross tabulation between selected industries and the perception of barrier T_Adptb_M ('Cannot be adapted to other industries'). High proportions of participants of the medical industry (>50%), pharmaceuticals & biotech industry (49%) and automotive industry (44%) agree on this barrier in comparison to smaller proportions of other industries (<= 38%). Nevertheless, the majorities of participants of the industries of consumer electronics (52%) and IT industries (57%) clearly disagree with the barrier and regard it as irrelevant for the diffusion of innovation. The chosen barrier item contributes to the interpretation of the according scale of the barrier variable.

Another example chosen is the examination of the cross tabulation between selected industries and the perception of barrier T_Cmplm_M ('No dominant design within an industry compared to o.T.’). High proportions of participants of the aeronautics industry (>78%), chemical (69%) and pharmaceuticals & biotech industry (69%) agree on this barrier in comparison to smaller proportions for consumer electronics (46%).

A third example is the examination of the cross tabulation between selected industries and the perception of barrier S_Orntn_C1 (‘Community of users is towards o.T.’). Smaller proportions of participants of the industries of consumer electronics (44%), IT (42%) and telecommunications (41%) agree on the barrier compared with the majorities of participants of the industries of aeronautics (57%), automotive (>50%), chemicals (65%), electric/electronic manufacturing (53%), medical industries (57%) and pharmaceuticals & biotechnology (69%). The chosen barrier item contributes to the interpretation of the according scale of the barrier variable.

More examples could be presented. Referring to the barrier variable of *context*, there exist significant differences for all three barrier items used (S_Cntxt_I, S_Cntxt_C and S_Cntxt_M). Therefore, more focus should be on the analysis of the according barrier variable, describing the *social context* of the social structure (S_Cntxt).

Barrier variables

As barrier items form the barrier variables, additional tests are performed by testing all barrier variables. Referring to Table M-10, the following table (Table 4-11) displays two variables that show significant differences among the industries with α smaller than .05.

Variable name	Description	LF-model origin
T_Adptb	Technology – *adaptability*	No
S_Cntxt	Social structure – *social context*	Yes

Table 4-11 – Barrier variables with significant differences for high-tech industries

Nevertheless, cross tabulation can allow insights into the frequencies of the levels of agreement between the listed Likert-type scales and the variable of industries as the illustrations from Figure 4-13 to Figure 4-21 show.

Larger proportions of participants of pharmaceutical and biotech industry (42%) agree with the barrier variable *adaptability* (T_Adptb) of the technology. A very small proportion of participants of pharmaceutical and biotech industry (16%) disagree compared with big proportions of participants of the chemicals (>40%), consumer electronics (40%), electrical/electronic manufacturing (44%), IT (58%) and telecommunication (40%) industries disagreeing. The majority of the participants of the IT industry (58%) disagrees with the barrier variable *adaptability* (T_Adptb) and does not see it as relevant (See illustrations from Figure 4-13 to Figure 4-21).

The majority of the participants of the pharmaceutical and biotech industry (58%) agrees on the barrier variable *social context* (S_Cntxt). Moreover, a larger proportion of participants of the medical industry (44%) agrees on the *social context* barrier variable (S_Cntxt) compared with smaller proportions of participants of the chemicals with 26% and IT industry with 28% (See illustrations from Figure 4-13 to Figure 4-21).

4.2.4.4 Variation between industrial and consumer goods

Due to a better suitability of non-parametric tests (see section 3.4.5.1), barrier items as dependant variables are tested on two independent samples from industrial and consumer goods with Mann-Whitney (Kuzon et al., 1996; Field, 2005). The following hypotheses apply for each Likert-type item and scale of the sequence:

H1_h3-0: ***μ (industrial good) = μ (consumer good)***

H1_h3-1: ***μ (industrial good) ≠ μ (consumer good)***

As follows, the results are described both for barrier items and barrier variables.

Barrier items

All statements of the barrier items were tested on significant differences. The results are illustrated in Table M-11. The barrier items of Table 4-12 show differences in their importance for diffusion of innovation at a significance-level smaller than .05:

Item name	Statement short form	LF-model origin
T_Cmplm_M	No dominant design within an industry compared to o.T.	Yes
S_Cntxt_C	Access is granted to small social groups	Yes
S_Orntn_C1	Community of users is towards o.T.	Yes
S_EnvAw_I	Not perceived as more environmentally friendly than o.T.	No
L_CstLrn_IC	High switching costs and learning efforts	Yes

Table 4-12 – Barrier items with significant differences between types of good

According to the frequencies of agreement (compare Figure M-3 and Figure M-4), respondents, who work with industrial goods, provide different agreements for the barrier items listed. With an analysis of cross tabulation (Saunder et al., 2007) between the listed barrier items and the variable of type of good (industrial or consumer good), the following results can be outlined.

Cross-tabulation is performed for the type of good and the perception of the barrier item T_Cmplm_M. As the following graphic (Figure 4-27) shows, a significantly larger proportion of participants working with industrial goods (65%) agree on the barrier compared with 54% of participants working with consumer goods.

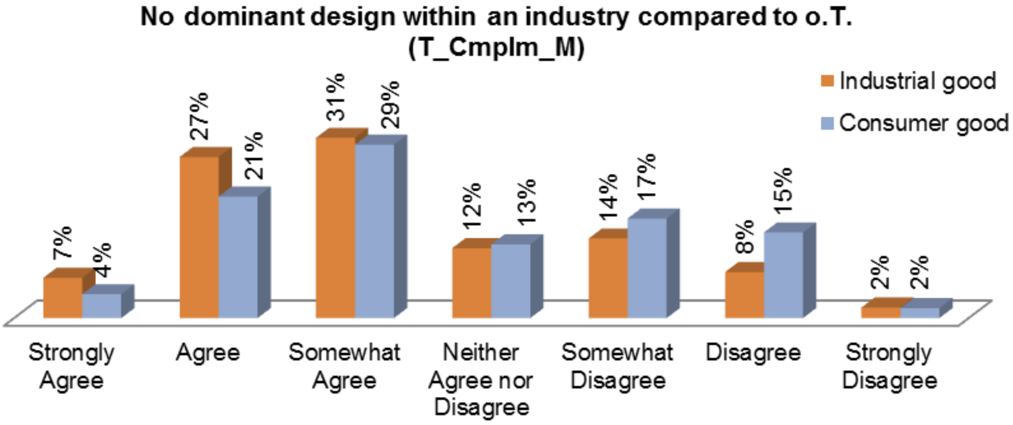


Figure 4-27 – Differences of a technology's dominant design regarding type of good

A second examination is the cross-tabulation of the type of good and the perception of the barrier item S_Cntxt_C. As the following graphic (Figure 4-28) shows, a significantly smaller proportion of participants working with industrial goods (<46%) agrees on the barrier compared to 53% of participants working with consumer goods.

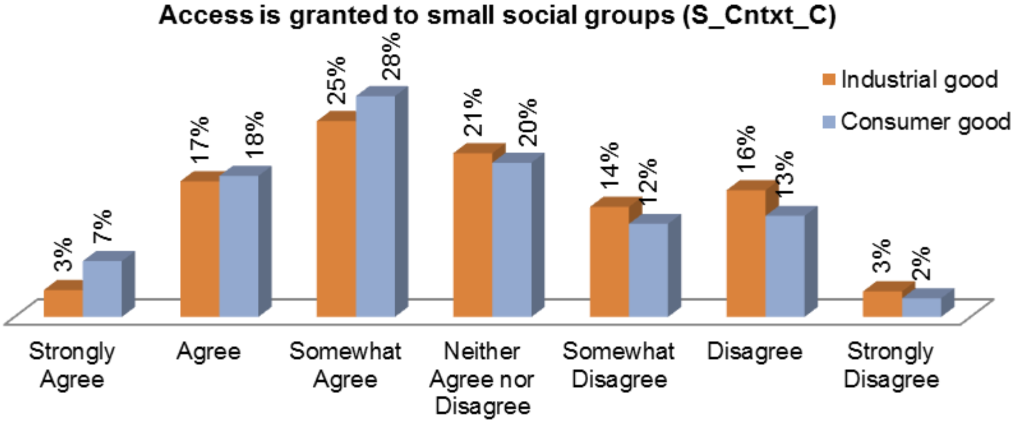


Figure 4-28 – Differences of group access to a technology regarding type of good

Another examination was the cross-tabulation of the type of good and the perception of the barrier item S_Orntn_C1. A significantly larger proportion of participants working with industrial goods (>58%) agrees on the barrier compared to 49% of participants working with consumer goods, as the following graphic (Figure 4-29) shows.

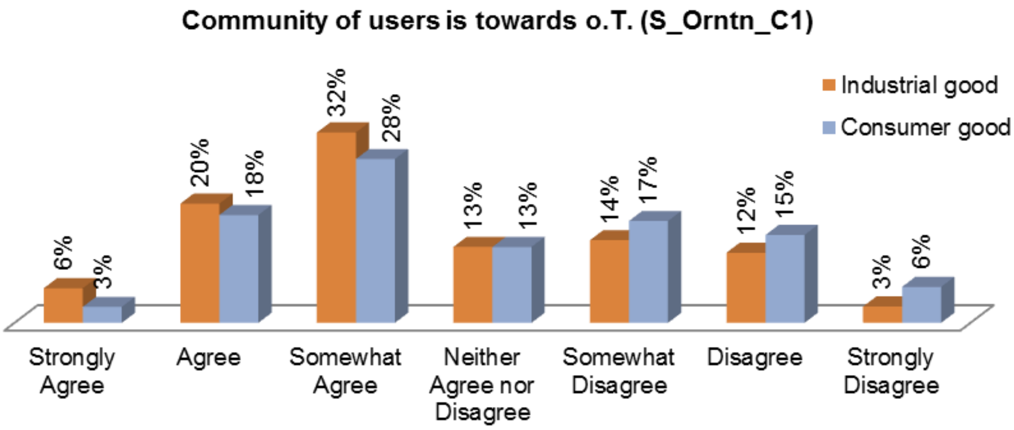


Figure 4-29 – Differences of community orientation regarding type of good

The cross-tabulation of the type of good and the perception of the barrier item S_EnvAw_I is examined as well. A significantly larger proportion of participants working with industrial goods (49%) disagrees on the barrier compared to 36% of participants working with consumer goods as the following graphic (Figure 4-30) shows.

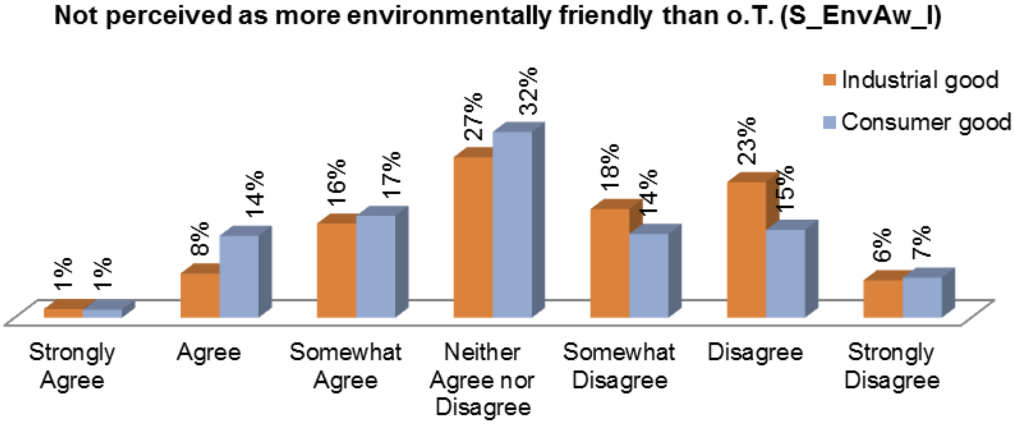


Figure 4-30 – Differences of perception to be green regarding type of good

Finally, the cross-tabulation of the type of good and the perception of the barrier item L_CstLrn_IC is examined. A significantly larger proportion of participants working with industrial goods (>75%) agrees on the barrier compared to 71% of participants working with consumer goods due to the following graphic (Figure 4-31).

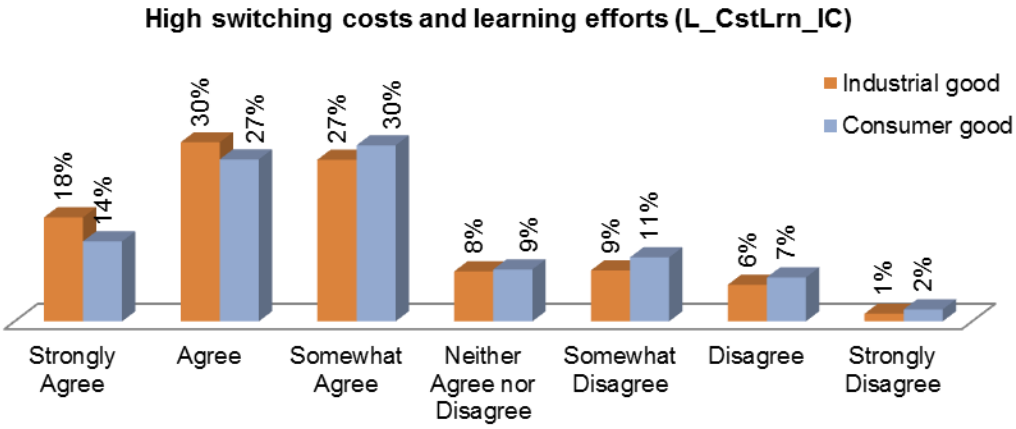


Figure 4-31 – Differences of switching/learning costs regarding type of good

Barrier variables

The described test results illustrate variations among barrier items, supported by illustrated cross-tabulation. As the barrier items form the barrier variables, additional tests were performed. All barrier variables represented by Likert-type scales were tested as well. Referring to Table M-12, the variables of Table 4-13 show significant differences among the industries with α as significance-level smaller than .05.

Variable name	Description	LF-model origin
T_Cmplm	Technology – *complementarity*	Yes
S_Cntxt	Social structure – *social context*	Yes
S_EnvAw	Social structure – *environmental awareness*	No

Table 4-13 – Barrier variables with significant differences between types of good

In addition to the test for significant differences, the comparison of tendencies as general statistic (compare Table M-13 and Table M-14) support the evaluation as well. The significant differences of the variables T_Cmplm, S_Cntxt and S_EnvAw are additionally illustrated by a swim lane chart (Figure 4-32) with median differences of the barrier variables. The central line represents a neutral position in agreement.

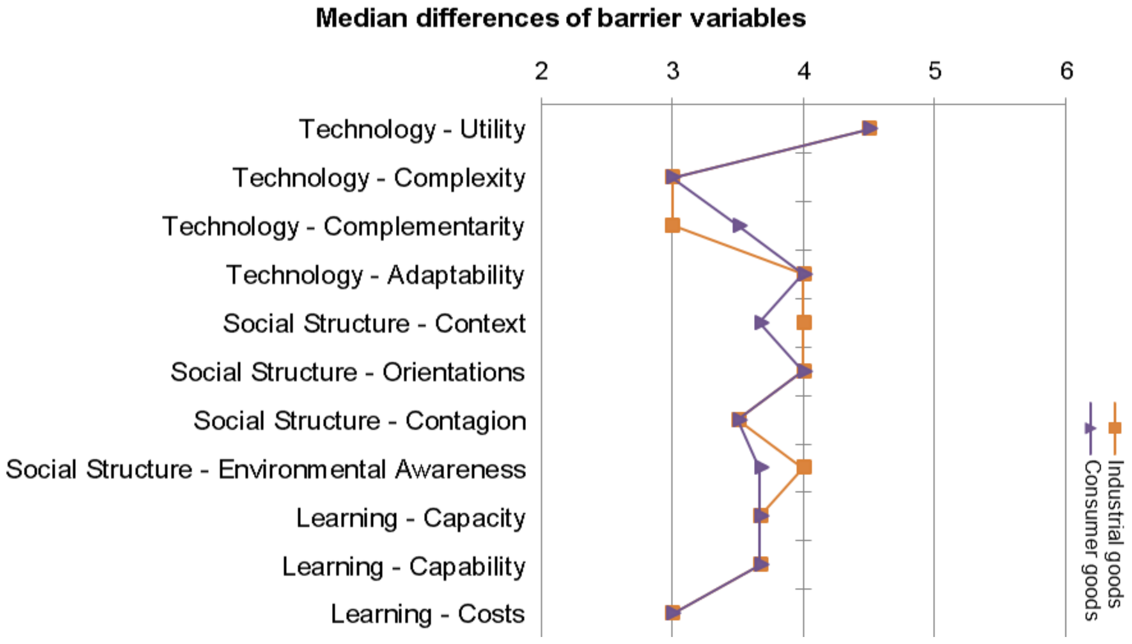


Figure 4-32 – Swim lane of barrier variable differences (median) with types of good

With an analysis of association between the listed barrier variables and the variable of the type of goods, the following results can be outlined. Cross tabulation is used for all barrier variables. Additionally, the following illustration (Figure 4-33) allows the comparison of summed up agreements between developed and emerging countries.

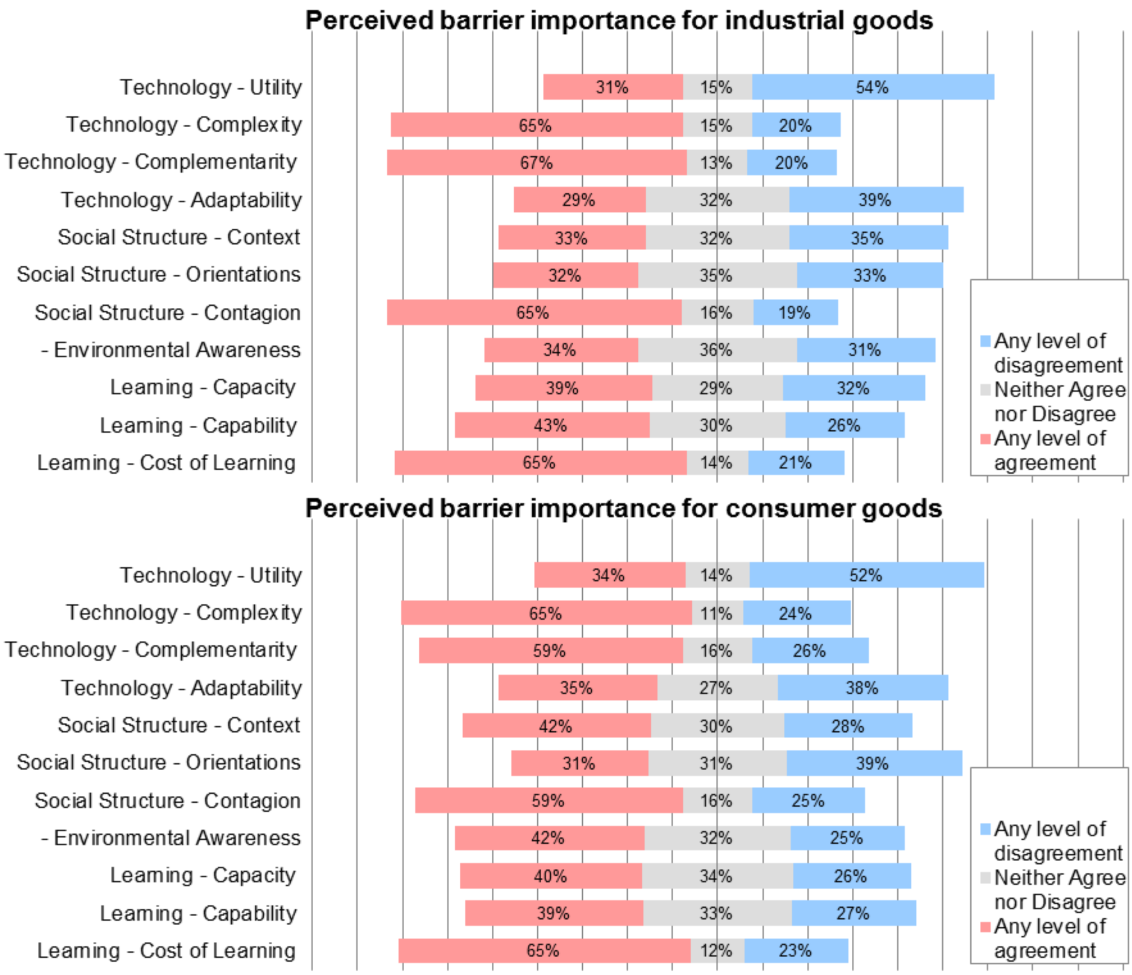


Figure 4-33 – Frequencies of agreement with barrier variables with types of goods

A significantly larger proportion of participants working with industrial goods (67%) agrees on the barrier variable of technological *complementarity* (T_Cmplm) of the compared with 59% of participants working with consumer goods.

A significantly smaller proportion of participants working with industrial goods (33%) agrees on the barrier variable of *social context* (S_Cntxt) as part of the social structure compared with 42% of participants working with consumer goods.

A significantly smaller proportion of participants working with industrial goods (34%) agrees on the barrier variable of *environmental awareness* (S_EnvAw) as part of the social structure compared with 42% of participants working with consumer goods.

4.2.4.5 Summary of variations

With the existence of differences in the importance of diffusion barriers and their presentation, variations are shown for different high- and medium high-tech industries. Additionally, results show variations between B2B and B2C businesses. These results show variations depending on the industrial context.

The results of the non-parametric techniques for testing variations and differences of ordinal data illustrate their ease of use (Whitley & Ball, 2002; Kothari, 2004). As the results of the tests for normal-distribution show, the ordinal data is to be analysed regarding differences applying non-parametric tests (Whitley & Ball, 2002; Kothari, 2004). The presented constraints described in section 3.4.5.4 are considered. For the exploratory approach, illustrations of frequencies are preferred over sharp statistics in order to support the results of the non-parametric tests for variations of the data.

The presentation of results for barrier items and results for barrier variables are similar which originates from the constitution of the barrier variables, consisting of two to three barrier items. Variations are also illustrated between developed regions as advanced economies and emerging regions, whose variable of economic regions shows correlations to some barrier variables. Correlations can also be analysed between variables from the LF-model and further barrier variables. The results of some correlations are presented in the following section.

4.2.5 Correlations of barrier variables

4.2.5.1 Hypotheses and justification for the tests of correlations

Several correlations are tested as part of this study. Correlation tests are performed with the variables of the LF-model (via hypothesis H2). Further correlation tests are performed to gain additional information on the possibility of incorporating additional barrier variables into the LF-model (via hypotheses H3 and H4). With strong correlations, the aspects of the additional barrier variables might already be represented within the LF-model.

Referring to the hypothesis H2, H3 and H4 about correlations among barrier variables (see section 3.2.3); several subordinate tests are performed to test the according null hypothesis. In the following sections the hypotheses are tested regarding different criteria. Each test is based on a subordinate hypothesis and according null hypothesis.

Clegg (1989) and Kothari (2004) suggest using non-parametric tests to analyse correlations of ordinal data due to their benefits (see 3.4.5.1 and 3.4.5.6.). Spearman's rank correlation coefficient is a suitable test (Field, 2005; Saunders et al., 2007) as is Kendall's τ (Goodman & Kruskal, 1979; Field, 2005). Because data of the barrier variables is regarded as ordinal data, correlations are tested by these two non-parametric methods. The test of Kendall`s τ was performed in its version b, assuming squared tables with a same scale width. The correlation tests were conducted to examine whether there was a correlation between the perceptions of the barrier variables.

With a significance level of $\alpha = 0.05$ for the Spearman rank-order and the correlation test by Kendall, it can be assured that the probability is less than 5% that the found correlation values occurred by chance if the corresponding null hypotheses were true.

The following sections describe the correlation tests between barrier variables. The tests of the hypotheses are performed via its subordinate hypotheses. In the following section all barrier variables originating from the LF-model are tested regarding correlations among each other.

4.2.5.2 Correlation tests with barrier variables from the LF-model

Hypothesis H2 regarding the existence of correlations of the diffusion barrier variables (see section 3.2.3) is tested based on the following subordinate hypotheses and according null hypotheses for the two-tailed test of the relationship of two barrier variables from the LF-model:

H2_h(x,y)-0: There is no correlation of (x) and (y) as LF-model variables

H2_h(x,y)-1: The variables (x) and (y) as LF-model variables correlate

The suitable correlation tests of Kendall`s τ and Spearman`s ρ were conducted as non-parametric tests (Clegg, 1998; Kothari, 2004; Saunders et al., 2007). With a significance level of α = .05, the null hypotheses that there is no correlation can be rejected with a probability smaller than the α-level for each combination according to Table N-1 and Table N-2. The strengths of the associations are also illustrated.

The results of the tests with Spearman`s ρ show positive correlations of the LF-model variables and mostly a medium strength (0.3 to 0.5). A strong correlation (> 0.5) exists for the relationship of *learning capacity* (L_Cpcty) and *learning capability* (L_Cpblt) and the relationship of *learning capacity* (L_Cpcty) and *orientations* (S_Orntn) in the social structure. A weak correlation (<0.3) exists for technology *complementarity* (T_Cmplm) and *social context* of the social structure (S_Cntxt). The results of the tests with Kendall`s τ show positive correlations and similar variances in strength.

As an overview is given for the correlations of the barrier variables of the LF-model, further correlations are researched for additional barrier variables. The following two sections describe correlations of the barrier variables *environmental awareness* and *adaptability* as candidates for extending the LF-model.

4.2.5.3 Correlations with barrier variable of technological adaptability

Hypothesis H3 from section 3.2.3 is tested based on the following subordinate hypothesis and according null hypothesis for the two-tailed test of the relationship of the barrier variables *adaptability* (T_Adptb) and technology *utility* (T_Utlty):

H3_h1-0: ***There is no correlation of T_Adptb and T_Utlty***

H3_h1-1: ***T_Adptb and T_Utlty as LF-model variable correlate***

Correlation results from tests with Kendall`s $\tau$ and Spearman`s ρ are presented. With a significance level of $\alpha = .05$, the null hypothesis that there is no correlation can be rejected with a probability smaller than the α-level according to Table N-3.

The results of the tests with Spearman`s $\rho$ shows strong positive correlation with $\rho = .513$. The results of the tests with Kendall`s τ (b) shows a medium strength with $\tau = .394$. The results show that the two variables clearly correlate, as the correlation coefficient is very high compared to correlations within the LF-model.

Additionally, the following subordinate hypotheses and according null hypotheses for the two-tailed tests of the relationship of the barrier variables *adaptability* (T_Adptb) and other technology-related barrier variables apply:

H3_h2-0: ***There is no correlation of T_Adptb and T_Cmplm***

H3_h2-1: ***T_Adptb and T_Cmplm as LF-model variable correlate***

H3_h3-0: ***There is no correlation of T_Adptb and T_Cmplx***

H3_h3-1: ***T_Adptb and T_Cmplx as LF-model variable correlate***

With a significance level of $\alpha = .05$ for these tests, the null hypothesis that there is no association can be rejected with a probability smaller than the α-level according to Table N-4 and Table N-5.

The strengths of the associations are illustrated and compared in the following table (Table 4-14) as coefficient values:

Variable name	Spearman's Rho	Kendall's tau
T_Utlty	ρ = .513 (strong)	τ = .394 (medium)
T_Cmplm	ρ = .446 (medium)	τ = .342 (medium)
T_Cmplx	ρ = .434 (medium)	τ = .335 (medium)

Table 4-14 – Correlation of adaptability with LF-model variables

The results of the tests with Spearman`s ρ show positive correlations and mostly a medium strength (0.3 to 0.5). A strong correlation (> 0.5) exists for the barrier variable of technological *utility* (T_Utlty). The results of the tests with Kendall`s τ show positive correlations and similar variances in strength.

Similarly, the following section describes correlations of the barrier variable of *environmental awareness* as the other candidate to be suggested as extending the LF-model.

4.2.5.4 Correlations with barrier variable of environmental awareness

In the following, hypothesis H4 from section 3.2.3 is tested based on the following subordinate hypotheses and according null hypotheses for the two-tailed test of the relationship of the barrier variables *environmental awareness* (S_EnvAw) with the LF-model variables of *social context* (S_Cntxt) and *orientations* (S_Orntn):

H4_h1-0: ***There is no correlation of S_EnvAw and S_Cntxt***

H4_h1-1: ***S_EnvAw and S_Cntxt as LF-model variable correlate***

H4_h2-0: ***There is no correlation of S_EnvAw and S_Orntn***

H4_h2-1: ***S_EnvAw and S_Orntn as LF-model variable correlate***

Similarly to the previous tests, non-parametric correlation tests with Kendall`s τ and Spearman`s ρ were conducted (Clegg, 1998; Kothari, 2004; Saunders et al., 2007). With a significance level of $\alpha = .05$ for these tests, the null hypothesis that there is no association can be rejected with a probability smaller than the α-level according to Table N-6 and Table N-7.

The result of the test for *social context* (S_Cntxt) with Spearman`s ρ shows a medium positive correlation with $\rho = 0.418$. The result of the test with Kendall`s τ shows a medium strength with $\tau = .310$. The results show that the variables are associated, but the strength is not strong.

The result of the test for *orientations* (S_Orntn) with Spearman`s ρ shows a weak positive correlation with $\rho = 0.277$. The result of the test with Kendall`s τ shows a weak strength with $\tau = .202$. The results show that the variables are associated, but the strength is not as strong as with S_Cntxt.

Additionally, the following subordinate hypotheses and according null hypotheses for the two-tailed tests for the correlation of *environmental awareness* (S_EnvAw) and other technology and social structure related barrier variables are tested:

H4_h(x)-0: ***There is no correlation of S_EnvAw and (x) as LF-model variable***

H4_h(x)-1: ***S_EnvAw and the variable (x) as LF-model variable are associated***

With a significance level of $\alpha = .05$ for these tests, the null hypothesis that there is no association can be rejected with a probability smaller than the α-level (see Table N-8, Table N-9, Table N-10 and Table N-11). The strengths of the correlations are illustrated in the following table (Table 4-15) as coefficient values.

Variable name	Spearman's Rho	Kendall's tau
T_Utlty	ρ = .307 (medium)	τ = .230 (weak)
T_Cmplm	ρ = .275 (weak)	τ = .207 (weak)
T_Cmplx	ρ = .234 (weak)	τ = .176 (very weak)
S_Cntxt	ρ = .418 (medium)	τ = .310 (medium)
S_Orntn	ρ = .277 (weak)	τ = .202 (weak)
S_Cntgn	ρ = .244 (weak)	τ = .183 (very weak)

Table 4-15 – Correlation of environmental awareness with LF-model variables

The results of the tests with Spearman`s ρ show positive correlations at a weak (0.2 to 0.3) or medium strength (0.3 to 0.5). The strongest correlation (> 0.4) exists for the barrier variable *social context* (S_Cntxt). The results of the tests with Kendall`s τ show positive correlations and mostly a weak strength (0.2 to 0.3). Very weak correlations (from 0.1 to 0.2) exist for the barrier variables of *contagion* (S_Cntgn) and technology *complexity* (T_Cmplx).

This section describes the existence of associations of *environmental awareness* as a candidate for extending the LF-model. In comparison to technology *adaptability* as barrier variable described in the previous section, *environmental awareness* shows weaker correlations to barrier variables originating from the LF-model.

4.2.5.5 Summary of correlation results

With tendencies and variations, results are presented regarding additional barriers subject to be inserted into the LF-model. Central tendencies show agreements on some barrier items. Variation results show that some additional barrier items not originating from the LF-model are perceived to be important in different industries and depending on economic regions or the type of good.

The tests of the previous sections illustrate whether additional barrier variables show strong correlation with LF-model variables. Potential modifications may change the internal consistency of the LF-model. The next section shows according test results.

4.2.6 Reliability evaluations regarding modifications of the LF-model

Cronbach's reliability tests are performed with all barrier item statements that originate from the LF-model, referred to as α (LF-model). Literature (Litwin, 1995; Mitchell, 1996; Field, 2005; Saunders et al., 2007) recommends applying the reliability tests with Cronbach´s α when assessing the reliability of survey data with Likert-scales.

With a value of .881 for α (LF-model), the reliability is evaluated as good (Cronbach, 1951; Nunnally, 1978; Field, 2005). This value provides a good internal consistency, whose need is discussed in section 3.4.7.3 regarding the reliability of the results.

To verify changes of the internal consistency with modifications of the set of barrier items, further tests are performed. Cronbach´s α is calculated with the different potential modifications to the LF-model. The resulting α-values according to Table O-2 and α (LF-model) are illustrated in the following table (Table 4-16):

Name	Description	Cronbach´s α
α (LF-model).	Model reliability with all items originating form LF-model	= .881
α (LF-model w/ T_Adptb)	Model reliability of the LF-model items and technology *adaptability* as additional scale (barrier variable) operationalised by three items	= .894
α (LF-model w/o S_Orntn_C1 & w/ S_Orntn_C2)	Model reliability of the LF-model items and the alternative item of orientation towards an even newer technology within the community of users	= .874
α (LF-model w/ S_Orntn_M	Model reliability of the LF-model items and industrial cooperation as additional item (barrier aspect) for orientations of the industry/market	= .884
α (LF-model w/ S_EnvAw)	Reliability of the LF-model items and *environmental awareness* as additional scale (barrier variable) operationalised by three items	= .885

Table 4-16 – Model reliabilities via Cronbach's α with modifications to the LF-model

As Table 4-16 shows, most of the suggested modifications result in a higher α-value. The biggest difference regarding the α-value shows the incorporation of adaptability as new LF-model variable, as an α-value of .894 can be achieved.

As the resulting α-value using the alternative barrier item of S_Orntn_C2 instead of S_Orntn_C1 is smaller than α (LF-model), the suggested modification was withdrawn as alternative barrier item during early analysis.

With the suggested modifications of two additional barrier variables (each with three additional barrier items) and an additional barrier item for the *orientations* variable of the LF-model, a higher reliability of the model can be achieved.

Gulliksen (1950) comments that a higher reliability can be achieved by a longer test. Having many Likert-type items would therefore result in high values for Cronbach´s α. Therefore, the same reliability tests with Cronbach are performed with the according statements for the conditions indices that originate from the LF-model. Although the absolute values for Cronbach´s α are slightly lower, the results are similar as Table O-3 shows.

As the resulting α-value using the alternative item of S_Orntn_C2 instead of S_Orntn_C1 is smaller than α (LF-model), the suggested modification was withdrawn. For the tests presented within this research, the item of S_Orntn_C2 remains out of consideration.

The reliability tests reveal the possibility of achieving a higher internal consistency by incorporating the barrier variables of *environmental awareness* and *adaptability* into the LF-model.

Besides the test results of central tendencies and variations, the tests for internal consistency show a higher reliability with the consideration of the additional barrier item describing a ‘missing inter-industrial collaboration’ (see Table O-1). This barrier item originates from the qualitative case study research. How this barrier and other barriers as results can be integrated as part of a mixed-methods approach is described in the following section.

4.3 Integration of results regarding the mixed-methods approach

Following a mixed-methods approach, this section describes the integration of results from qualitative and quantitative research methods. The case study research as qualitative method is about diffusion problems for digital radio in Germany. A cluster analysis evolves different barriers by mapping supporting clusters to the barrier of the LF-model as explained in the sections 4.1.5 and 4.1.6. The subject of digital radio describes an industrial segment of the production and distribution of audio content.

The quantitative research is presented by the results of an online questionnaire in which participants from several industries evaluated statements of barrier items. A suitable tendency analysis of the barrier items is used to question whether the results of the case study research can be confirmed by the questionnaire and generalized for other industries.

An initial evaluation of the frequencies of agreements with the different statements for the barrier items from the industry subgroup of media production/distribution with a population of N=26 shows a certain agreement with some of barriers according to Figure P-1.

Referring to the central tendencies of Table P-1, eight Likert-type items (T_Cmplx_M, S_Orntn_M, S_Cntgn_IC, S_Cntgn_M, L_Cpcty_M, L_Cpblt_I, L_Cpblt_M and L_CstLrn_IC) show clearly the lowest values for mode and provide strong agreement on the statement by that subgroup. Among the barrier items with moderate agreement are T_Cmplx_IC and T_Cmplx_M contributing to the barrier variable of *complexity*, as well as T_Cmplm_IC and T_Cmplm_M, contributing to the barrier variable of *complementarity*. Four barrier items (T_Utlty_IC, T_Adptb_C, S_Cntxt_M and L_Cpblt_C) show disagreement on the statement by representatives of that subgroup.

Compared with the barrier results of the case study research, the barrier items of a 'missing inter-industrial collaboration' (S_Orntn_M), no achieved contagion (S_Cntgn_IC), a poor execution of marketing (S_Cntgn_M) and the industry not allowing an introduction of innovation very frequently (T_Cmplx_M) are perceived to be very important by the respondents. The respondents only represent a small subgroup of the sample who works in the industry of media production & distribution. However, their perception of the statements of the questionnaire is considered for integrating the results of the case study research and the survey.

The following table (Table 4-17) illustrates which barriers resulting from the clusters analysis (left column) are strongly and considerably agreed on by the perceptions of barrier item statements (right column) and those, which are not confirmed.

ID	Barrier items for digital radio identified in the LF-model	Supporting clusters	LF-model barrier item	Agreement
LF1	No perception of digital radio (DAB) as technology of higher utility but of higher costs	**C1**, C5, C6	T_Utlty_IC	(Disagreement)
LF2	Complementarity of FM results in higher total utility	**C11**, C6	T_Cmplm_IC	Considerable
LF3	Digital radio (DAB) does not lead to a dominating design due to the global availability of FM	**C11**	T_Cmplm_M	Considerable
LF4	Constraint of regional access on behalf of proprietors	**C10**, C7	S_Cntxt_M	(Disagreement)
LF5	No contagion of digital radio (DAB) among listeners	**C4**	S_Cntgn_IC	Strong
LF6	Lack of marketing and marketing errors in the past	**C3**	S_Cntgn_M	Strong
LF7	Focus of attention is on listening radio not on newest service	C1	T_Cmplx_IC	Considerable
LF8	Complexity of radio industry renders really new innovation less frequent	C5	T_Cmplx_M	Strong
BI1	Lack of industrial alliances for consensual orientation towards digital radio (DAB)	**C2**, C7	S_Orntn_M	Strong

Table 4-17 – Confirmation of identified barrier items for digital radio by the survey

As Table 4-17 shows, most barrier items resulting from the case study research, mapped to by the according cluster (out of the cluster analysis), are confirmed by survey research. Two out of the nine barriers presented are perceived as not important by the respondents of the questionnaire and are listed with disagreement.

The following graphic (Figure 4-34) illustrates by the intersecting set that most barrier items presented by the qualitative research are confirmed by quantitative research via the according industry subgroup of the survey.

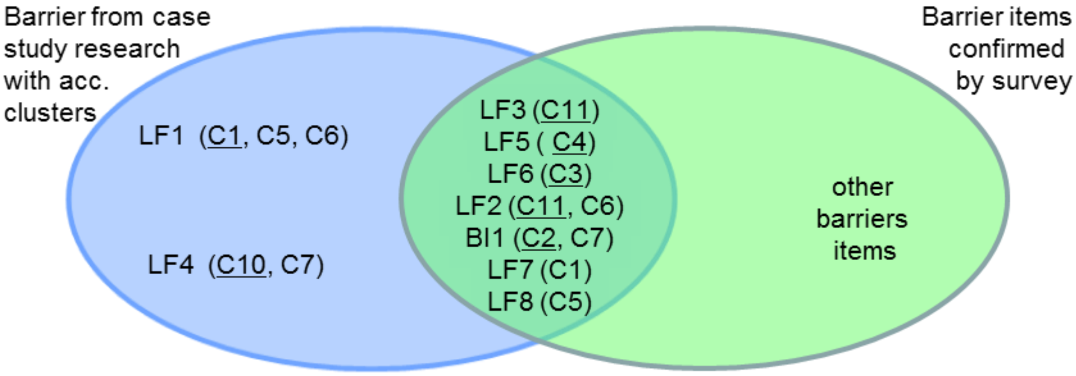


Figure 4-34 – Intersection of diffusion barriers from case study research and survey

The illustrated barrier items are regarded to be existent and important within the industry of media production/distribution. In a similar way, central tendencies of the barrier items can be described for the sample of technology-intensive industries with a samples size of 726. Comparable results are achieved with this bigger sample according to of Table K-2. The barrier items, which are regarded to be confirmed and which are disagreed on, are the same as in Table 4-17. The differences are that the barrier items of ‘missing inter-industrial collaboration’ (S_Orntn_M) and a missing contagion (S_Cntgn_IC) are not as strongly agreed on as with the subsample of the media production & distribution industry.

This section illustrates the integration of results from qualitative and quantitative research. Besides the results of the case study research, their confirmation and generalization, further results are presented as part of the survey analysis. The next section gives a summary of all results.

4.4 Summary of results of the empiric research

With the presentation and integration of qualitative and quantitative empiric results, the researched diffusion barriers are presented in quite different ways. Regarding the case study research, the results of a cluster analysis are shown and the mapping of supporting clusters to the barriers of the LF-model is presented. The identified clusters support six barrier items (each with one dominating cluster) of the LF-model. Two barrier items of the LF-model are supported without a dominating cluster. An additional barrier describing non-existing inter-industrial collaboration is strongly supported by its cluster.

Referring to the survey, several results originating from the participants' agreement with statements of barrier items and variables are presented. Most results refer to hypothesis H1 by presenting variations among diffusion barriers and differences between economic regions, industries or types of good. For generalization, agreements on the importance and relevance of barriers by the high-tech and medium high-tech sample were evaluated. Two barrier items from the LF-model are agreed on with strong and 13 with considerable evidence. The respondents disagree with five barrier items.

Barriers not being part of the LF-model are presented as well. As part of the cluster analysis of the case study research, additional challenging problems for the introduction of a new technology are mentioned. The challenging problems are tested as barrier items and variables with the survey via reliability analysis, central tendencies, variations and also correlations. As the results confirm their importance, with 'missing inter-industrial collaboration' an additional barrier item and two additional barrier variables (technological *adaptability* and *environmental awareness* of the social structure) are suggested to be incorporated into the LF-model.

The integration of outcomes from the mixed methods applied is presented in the previous section. The results of the different research methods as part of a mixed-methods approach are discussed in the following chapter.

5. Discussion

This chapter discusses the results of the empiric research via the initial case study research and the survey to practitioners. It presents the most important aspects identified in the results and their meaning. Their integration is discussed due to the mixed-methods approach. Some cross-links refer to the results in chapter four.

5.1 Barriers evolving from case study research results

5.1.1 Diffusion barriers for digital radio in Germany

Expectations for digital radio technology were high regarding its introduction in Germany and all over Europe about two decades ago. The vision was that "…one day there will be a new portable which will consist of a DAB data receiver and a telephone. (…) In addition to the Walkman and the Watchman, why not a Dataman?" (Müller-Römer, 1994, p. 6). Referring to the vision from the 1990s, the diffusion of neither DAB nor its improved version DAB+ has been taking place successfully in Germany. The case study research findings from chapter four illustrate different reasons for the failed diffusion, which evolve as clusters from cross-site analysis. The most critical clusters are identified as barrier clusters. Some clusters are supported by literature about the diffusion of digital radio. As some barrier clusters support parts of the LF-model, the according barrier items are presented with a contextual wording in section 4.1.6 (LF1, LF2, …). The barrier clusters are discussed in the following paragraphs.

The main problem stated as barrier is the missing benefit of the technology. Additional choice, more services and higher sound quality were and are not perceived as added values. These findings support those of Töpfer (2008) and Anderson (2013) regarding digital radio. Added values were only theoretically present at the beginning of the technology in the 1990s, neither a better sound quality was perceivable, nor was there more choice as the provided contents were the same as with the old technology of FM.

Today, those features are provided with the availability of mobile internet. The missing benefit as finding supports similar studies such as Moore and Benbasat (1991), as well as findings regarding relative advantage as critical innovation attribute of Rogers (2003), and regarding a value barrier of Ram and Sheth (1989), Hess (2009) and De Ruyter et al. (2001). The overall technological utility was not perceived to be higher than the old technology and therefore a higher price was not accepted. These findings support studies on digital radio by Goldhammer et al. (2008), Töpfer (2008), Anderson (2013) and the general findings of Zeithaml (1988). Today, individuals rather think of investing their money in mobile internet technologies instead of digital radio.

The focus for individuals regarding the technology is on listening to their radio program as a basic application and not on additional features. For decades, radios have been used while focusing the attention on other activities, such as driving a car or cooking. Most individuals would not focus on the new features of digital radio. This supports other general findings about the attention on overall effectiveness of Moreau et al. (2001).

Among other barriers, a lack of marketing and a missing contagion have hindered the diffusion of digital radio as a mass application. The finding of a lack of marketing supports the findings of Jain (2001) about different marketing failures as a misunderstanding of customer needs, poor positioning and no clear differentiation. More marketing effort should have been put into the introduction of the new technology. This finding supports those of Calantone et al. (1993). The little marketing performed is regarded as too technology-oriented according to an interviewee. It did not focus on the perceivable benefits, as the argumentation of a better sound quality and more choice could not be perceived. A cause for this may be the lack of industrial cooperation, as marketing was performed by stakeholders differently and at different points in time.

It is also mentioned that for a long time no contagion was achieved with digital radio in Germany, which support Töpfer (2008) and Anderson (2013). This finding supports the similar findings of Richins and Bloch (1986), Burt (1987) and Bruland (1995). It also supports those of Jain (2001) about timing failures. Digital radio diffusion simply took too long. Mobile internet has overtaken terrestrial digital radio during the race of diffusion as the cluster, describing ‘Internet as a technological substitute’ (C6), shows. The cause may be that digital radio without clear and perceivable added values did not become popular and nobody spoke about it. Thus, a positive word-of-mouth effect has not taken place.

One barrier cluster describes regional constraints due to the German political history. The findings support several other publications about digital radio (Goldhammer et al., 2008; Tzschaschel, 2011; Anderson, 2013), as nation-wide radio was not in the interest of the Allies in the post-war years of the 1950s and 1960s. The German government could have supported by changing this constraint from the beginning. The missing governmental help as finding supports those of Lawton (2008). Findings of governmental constraints as context support the findings of Taylor et al. (2003) and Hall and Khan (2003). Additionally, the constraints support the findings regarding environmental failure of governmental regulation of Jain (2001).

The findings also show that the digital radio technology struggled because it could barely provide the same worldwide complementarity as FM. FM results in a total higher utility considering the availability of mobile internet as adjacent technology. The findings support the investigations of Shy (2001) as part of the LF-model but also additional investigations related to a ‘technology lock-in’ (Weiber, 1992, 1995; Schoder, 1995; Garrone et al., 2002).

A dominating design was not achieved in contrast to FM technology. This supports the investigations of Abernathy and Utterback (1978). The complexity of the network industry seems not to allow the introduction of a new technology very frequently. This finding supports those of MacVaugh and Schiavone (2010).

Considering digital radio as a lock-in situation of broadcasting as a network industry (Schoder, 1995; Weiber, 1992, 1995; Garrone et al., 2002), the introduction of the technology was not sufficiently harmonized. This could have been performed either by governmental institutions or by industrial cooperation. A missing inter-industrial collaboration is found as being a major problem for the failed introduction of digital radio. It supports the argumentation of Goldhammer et al. (2008). One industry was waiting for the move of another. Content providers claimed that no receivers were available and receiver manufacturers claimed that no content was available. With a well-structured stakeholder management and a proper coordination (e.g. by the government), the introduction could have been harmonized more effectively. In spite of a different industry, this supports similar findings of Margolis and Zuboy (2006).

During the long time of its introduction, other technologies became available. The added value of having a ‘dataman’, as Müller-Römer described the digital radio of DAB in 1994, is completely taken away by new portables with mobile internet such as smartphones. No benefit is perceived anymore compared to the old technology of FM in combination with smartphones which provide high-speed internet access.

To conclude, several co-existent explanations of why no diffusion of digital radio took place in Germany are outlined. Following the first two research objectives, the diffusion barriers are presented with different importance. The major barrier identified is a lack of technological utility. Another aspect is the missing inter-industrial collaboration during technology introduction. Some digital radio problems described by others (see section 4.1.1.2) are confirmed and supported (Steinheber, 2014).

The example of digital radio was analysed following an exploratory approach, using the LF-model as reference. Many barrier clusters could be identified as well in the LF-model, as the rewording of its barrier items shows. As the interaction with multiple LF-model conditions (technology-related and social structure-related barriers) by multiple players (listeners and stake holding industries) resulted in negative feedback, the result was non-adoption, which is shown by the cluster C0, describing that no diffusion was achieved. This finding supports the finding of the systematic instance by MacVaugh and Schiavone (2010, p. 206).

As the descriptions of barrier clusters (section 4.1.3) show, the barriers are related with each other. As clusters could be mapped to the LF-model, consequently, this also gives proof of certain interdependencies within the LF-model.

It could be shown that most of the introduced findings for the digital radio case can be found in the LF-model. It needs to be discussed whether all findings can be generalised both for the media industry and for other technology-intensive industries. Therefore, the findings were included in a survey by their operationalization via barrier items (mostly originating from the LF-model). Aspects relating to a confirmation and generalization of the findings are explained in the following section.

5.1.2 Confirmation and generalization of findings

Referring to the case study research describing problems of digital radio adoption in the media and broadcasting industry in Germany, the mentioned barriers from section 4.1.6 (LF1-LF8, BI1) were tested in the questionnaire with the general statements of the LF-model. The central tendency results of the questionnaire with the according subgroup 'media production and distribution' shows agreement with seven of the nine suggested barrier items, as illustrated in section 4.3.

The survey with the industry subgroup confirms the existence of four barriers as part of the case study research results by strong agreement. One barrier identified (LF6) is a lack of marketing (barrier cluster from section 4.1.3.8) and is confirmed via S_Cntgn_M. It supports the findings of Calantone et al. (1993). The barrier of 'missing inter-industrial collaboration' (BI1) from section 4.1.3.6 is confirmed by the results of S_Orntn_M. This finding supports similar argumentations of Margolis and Zuboy (2006), Goldhammer et al. (2008) and Anderson (2013). A further barrier is a missing contagion (LF5), supporting findings referred to in the LF-model (Richins & Bloch, 1986; Burt, 1987; Bruland, 1995) via the item S_Cntgn_IC. That a complex and radically new technology cannot be introduced that frequently is another barrier (LF8), confirmed by the survey with strong agreement on the item T_Cmplx_M. This is an important aspect especially in networking industries according to MacVaugh and Schiavone (2010). However, the latter barrier has not a dominating supporting barrier cluster but refers to the argumentation that the old technology is an established worldwide standard and a new technology cannot be introduced. All barriers are especially important in network industries, in which new innovations cannot be introduced very frequently. In network industries, the number of potential adopters is very high and individual decision-making is important. Inter-industrial collaboration is required for harmonising the introduction of the technology. Marketing is important to achieve a fast diffusion of the innovation.

The barriers describing technological *complementarity* (LF2, LF3) and *complexity* (LF7) of the radio standards are confirmed with considerable evidence by the survey results of the according barrier items (T_Cmplm_IC, T_Cmplm_M and T_Cmplx_IC). The situation of FM as a dominating technology with worldwide usage for more than 50 years is quite unique. The complementarity may not be agreed on as strongly, because other technologies within the media production and distribution industry do not have such a worldwide and historic presence.

According to the case study research findings, the barrier of missing perceived technological utility and added values (LF1) is presented as most important barrier. This supports the findings of Davis (1989) and Moore and Benbasat (1991). If the added value and benefits (the utility of a technology) are not perceived to be better than the old technology, the adoption of the technology may not happen. However, the according barrier item of missing perceived technological utility and added values (T_Utlty_IC) is negated by the questionnaire results. Assuming that technologies are adopted for utility-maximizing, an evaluation of the benefit of a certain investment is performed. Therefore, the perception of a utility may be of minor importance in comparison to other barriers. Contextual access constraint for digital radio on behalf of proprietors as another barrier (LF4), tested via the barrier item of S_Cntxt_M, is disagreed with in contrast to findings of Taylor et al. (2003) and Hall and Khan (2003). These results can be explained by the very special focus of the German case study research. The participants of the survey are from all over the world and might not find a similar constraint due to the political history as in Germany.

According to the questionnaire results of the media subgroup, some barriers are perceived to be more important and might hinder an innovation in the media production and distribution industry. However, the results of the questionnaire with the according subgroup may have limitations for confirming the case study research results. This is because of the very specific industry and technology of DAB/DAB+ and Germany as a relatively small region. The subgroup of media production & distribution as part of the sample consists of survey participants of all around the world, who may have experience with different technologies in their industrial environment.

Therefore, the case study research findings are as well tested with the sample of focus (technology-intensive manufacturing industries) according to section 4.3. As digital radio is a very specific technology in the special regional situation of Germany, the questionnaire results with the sample of technology-intensive industries may be too broad. Nevertheless, they show a common agreement with most of the barriers as findings of the case study research. The same barriers as with the related industry subgroup are agreed or disagreed on. The differences are that the barriers of ‘missing inter-industrial collaboration’ (BI1 via S_Orntn_M) and a missing contagion (LF5 via S_Cntgn_IC) are not as strongly agreed on as with the subsample of the media production and distribution industry. This can be explained as the participants’ evaluations are performed in the context of other industries, which may not be network industries such as the industry of broadcasting with digital radio.

Integrating the results from section 4.3, it can be said that most of the barriers from the case study research are confirmed by the suitable subgroup of the according industry. It seems that the additional barrier BI1 can also be generalized for other industries. Embedding the findings in the LF-model is therefore discussed in the next section.

5.1.3 Embedding findings into the LF-model

The results of the case study research from section 4.1 show that many links can be established to the barrier items and barrier variables of the LF-model. The different dimensions of the LF-model with levels of influence and the domains of individuals, community and the macro-level of industry can be applied quite well for describing the situation of the diffusion of digital radio as new technology (Steinheber, 2014). The model is recently also referred to in publications regarding other high-tech industries such as consumer electronics with photography (Schiavone, 2013, 2014), automotive (Terporten et al., 2012) and IT (Lee et al., 2014).

The findings of the case study research are tested with the wordings of the LF-model. As Table 4-17 from section 4.3 shows, the general LF-model wording can be applied effectively to the technology of digital radio as new technology and FM as old technology. The findings are confirmed and are subject to be generalised. They support the barrier items as part of the LF-model.

As the mapping of barrier clusters to barrier items (see section 4.1.6) and to barrier variables of the LF-model (see section 4.1.5) shows, there is only one barrier as finding for digital radio, which is not part of the theoretical LF-model. Inter-industrial collaboration (BI1, operationalized via S_Orntn_M) with a common orientation is presented as an important result of the case study research. The barrier refers to the variable of *orientations* of the LF-model. As an outcome of the case study research findings, the aspect of an absence of inter-industrial collaboration can be considered a limiting barrier for the diffusion of an innovation. This represents a contributing modification of the macro-level domain of an industry/market for the LF-model and is supported by Goldhammer et al. (2008) and Margolis and Zuboy (2006). Therefore, it is suggested to be incorporated into the LF-model to fill the existing empty spot (see Table Q-2) as illustrated in the following scheme Figure 5-1.

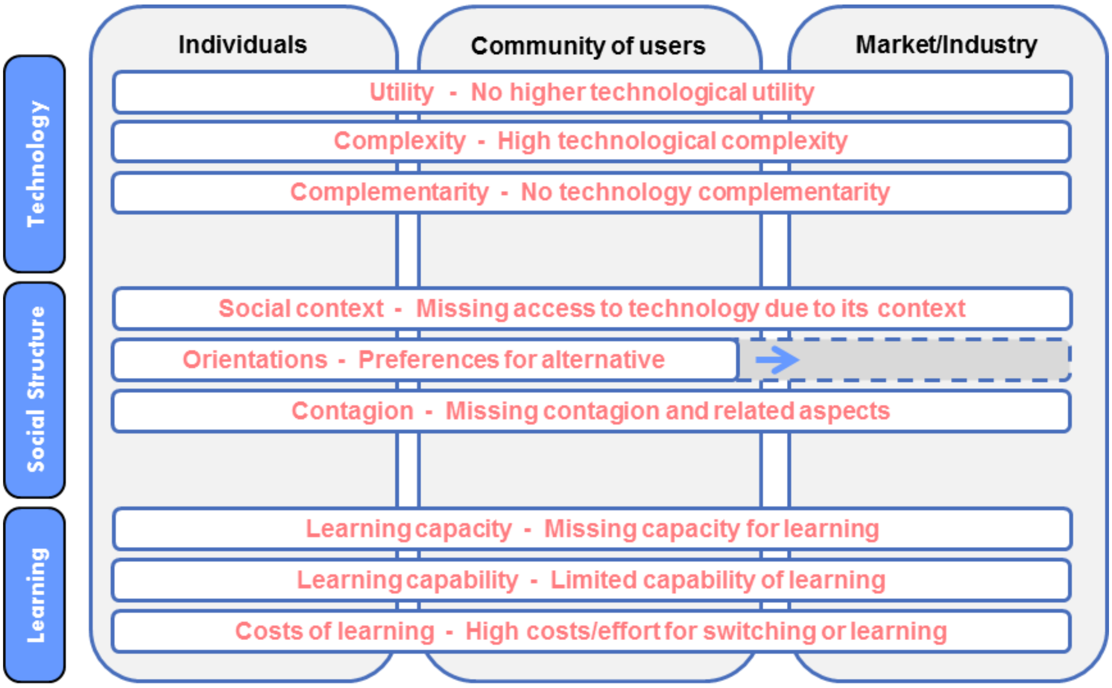


Figure 5-1 – Complementary modification of LF-model (scheme)

The barrier clusters considered as findings evolve from the cluster analysis of the case study research. Internet as a technological substitute for potential leapfrogging does not support any barrier item as dominating barrier cluster (see section 4.1.3.2). Besides barrier clusters, further clusters were also identified, according to section 4.1.4.

A lack of adaptability or upgradeability of innovation is mentioned as a cluster (C9) but it is not considered as major problem for digital radio diffusion. Aspects of adaptability are explained in various publications regarding re-invention (Berman & McLaughlin, 1977; Wolfe, 1994; Rogers, 1995; Nutley et al., 2002; Petkova et al., 2010) and regarding the perception of individuals (Richerson, 2001; Steinheber & Chlupsa, 2012).

The aspect of an innovation to be an environmentally-friendly solution represented by cluster C8 is not seen as that important for digital radio diffusion either. The aspects of environmental awareness are also not directly considered in the LF-model.

A further resulting cluster is internet as adjacent but also substituting technology for radio (C6). The decision for digital radio adoption may recently not be made as individuals wait for newer and even better technologies with mobile internet. To generalise, a technology adoption might not occur, because a new generation or even a better technology is already available or under discussion. This is referred to as leapfrogging and relate to the findings of Mahajan and Muller (1996) and Bardhan and Chanda (2007). It may be a reason for a negative orientation towards a technology. The LF-model variable of *orientations* does represent an orientation towards the old technology but there may be an additional orientation towards an even newer technology. The meaning and consequence would be similar.

While the barrier of ‘missing inter-industrial collaboration’ as finding can be embedded in the LF-model structure, other evolving clusters cannot be identified in the LF-model. However, the clusters of an even better available technology (C6, described in section 4.1.3.2), no green perception in our society with high environmental awareness (C8, described in section 4.1.4.) and missing upgradeability (C9, described in section 4.1.4.) may turn out to have effects as barriers for other technologies in other industries.

Following the second research objective, the findings show variations in the importance of barriers for digital radio. To discuss the implication of the results, an approach for their confirmation is presented. Following the first research objective of identifying important barriers, with ‘missing inter-industrial collaboration’ a barrier is identified, which so far is not sufficiently described in literature. The presented findings for digital radio describe a lack of marketing as reason, which is not mentioned in digital radio diffusion research for Germany. The findings of the case study research also provide valuable information for technology introductions in other media network industries.

Besides the findings of barrier clusters, further clusters are identified which may be problematic for other industries. Therefore, suitable statements were operationalised for the quantitative online questionnaire. The questionnaire consists therefore of statements describing barrier items from the LF-model, a statement representing the barrier item of ‘missing inter-industrial collaboration’ and further statements, presented in section 3.4.2.1. The questionnaire results regarding these barriers but also regarding other barriers originating from the LF-model are discussed in the next section.

5.2 Survey results

5.2.1 Variation of agreements with barriers from the LF-model

5.2.1.1 Barrier items and central tendencies

The focus of researching the LF-model is on its variations in the importance and relevance of the different barrier items and the levels of influence as barrier variables of the LF-model. Following the research objective of identifying barrier differences, the online questionnaire asked for the agreement of barriers originating from the LF-model and further barriers as results of the case study research. The survey evolves variations among the barrier items and differences of the importance of barriers depending on the industrial context, the type of good and the economic region.

The results of the survey and the tests of central tendencies show that the importance and existence of the different barriers are perceived quite differently by the respondents. The survey contains both, barrier items from the LF-model and barrier items being subject for extending the LF-model. Within this section, those barrier items are focused on in detail, which originate from the LF-model. Focusing on technology-intensive industries, agreement is given in different strengths (see section 4.2.3.1). With different agreements, some barrier items of the LF-model can be identified as more important than others. Among the barrier items, there are two barrier items that show a very strong agreement and more than a dozen with considerable agreement, of which some are described as part of this section.

According to the respondents from very different technology-intensive industries very complex technologies cannot be introduced very frequently (T_Cmplx_M). This finding is seen as an important barrier and supports those of Song and Montoya-Weiss (1998) and MacVaugh and Schiavone (2010) but also the findings of innovation attributes of Rogers (2003). It may be perceived as very important, because the sample consists of respondents mainly working with technology-intensive goods. As industrial or investment goods consist of a mix of technologies and are often integrated into complex production processes and according logistics, new technologies cannot be introduced very often. A comparison of frequencies can be made by comparing Figure M-3 and Figure M-4. However, further research is required to explore the reasons for the importance and relevance of this barrier.

Another barrier item, perceived to be very important is a lack of marketing (S_Cntgn_M). The community of potential users of the technology would not be aware of its existence if marketing operations did not work well. This barrier item supports the findings of Calantone et al. (1993) and Moore (2006) regarding marketing. This finding also supports the findings of different marketing failures of Jain (2001). Its importance may be perceived as very high, because marketing considers the preparation of the market regarding communication to very different stakeholders and preparing material like instructions. These activities may especially be important for industrial goods in technology-intensive industries regarding the communication to various stakeholders (users, maintenance personnel, and service engineers) and according provision of learning material. Additional research is required to investigate the reasons for this strong agreement. These aspects also support the findings of Easingwood and Koustelos (2000) and MacVaugh and Schiavone (2010). The consequence of bad marketing may be a low recognition in the market or individual orientations towards the older technology.

Considerable agreement is achieved for the barrier item describing a missing contagion (S_Cntgn_IC), which supports the findings of Moore (2006) regarding a chasm in the technology adoption cycle and those of Jain (2001) regarding timing failure of technology introduction. It also supports the findings of Richins and Bloch (1986), Burt (1987) and Bruland (1995). A missing contagion as barrier is the result of active resistance of many individual decisions of non-adoption, which supports the findings of Ram and Sheth (1989) and Hess (2009). The barrier items may be perceived as important because the longer the diffusion takes, the higher is the possibility of other technologies, being developed with an even better performance. Another reason may be scale effects for the production of such technologies and consequently its availability at a lower price on the market. Different reasons may be questioned in detail by further research.

The barrier item describing the orientation of the community towards the older technology (S_Orntn_C) shows as well considerable agreement by the sample of focus. This supports the findings of Brown and Duguid (1991), Rogers (1962) and Wenger (1998), who also support the LF-model. The findings also support the findings of a tradition barrier by Ram and Sheth (1989) and Hess (2009), who refers to Antioco and Kleijnen (2007) for empirical results. As a community consists of a group of individuals, the finding also supports those by Hess (2009) regarding cognitive barriers and resistance due to biases, e.g. a status-quo bias (e.g. Samuelson & Zeckenhauser, 1988; Inman & Zeelenbert, 2002; Garville, 2005). This finding may be explained by the tendency of high-tech communities of not touching and changing a running system (e.g. production processes) by an investment good with a new technology. Additional research is required about the reasons for the strong agreement with this barrier item.

Considerable agreement is achieved for the barrier items describing the variable of *complementarity*. This supports the findings of Shy (2001) regarding a resulting higher total utility with a complementary old technology (T_Cmplm_IC). It supports as well the findings of Ram and Sheth (1989) and Hess (2009) and relating findings (Ellen et al., 1991; Mukherjee & Hoyer, 2001; Rogers, 2003) regarding a barrier of not using a technology due to its missing compatibility. Moore's (2006) argumentations on this aspect are also supported (see Table 2-7). On a macro-level, the findings support those of Abernathy and Utterback (1978) about the extent that a new technology does not provide a dominant design in the market/industry (T_Cmplm_M).

Besides items with strong agreement, most barrier items show considerable agreement (e.g. examples with missing contagion, community orientation or complementarity items) or a very neutral evaluation on the agreement scale. However, there are also barrier items that show disagreement. The existence and importance of four barrier items as part of the LF-model are not agreed on, of which one has to be mentioned with strong disagreement.

That access to a new technology is not granted e.g. by the government (S_Cntxt_M) is not seen as important barrier with considerable disagreement. The finding is in contrast to the findings of Tayler et al. (2003) and Hall and Khan (2003). The importance and existence of this barrier item may be in very special situations as for example the one of digital radio in Germany. A generalization for several industries all over the world seems not to be possible but further research is required to explore different reasons for different industries.

Another barrier considerably disagreed with by the participants of the technology-intensive industries is a barrier describing that individuals are oriented negatively towards its use (S_Orntn_I). This finding is in contrast to several findings referred to in the LF-model (Bruland, 1995; Kingsley & Anderson, 1998; Morris & Venkatesh, 2000). The findings of Moore (2006) are also not supported. Neither can the findings support those of Hess (2009) regarding decision biases and cognitive barriers nor the ones of Ram and Sheth (1989) about negative image associations and social risk. As a big portion of the respondents rather work with industrial goods in B2B businesses, adoption decisions may mostly not be made by an individual but by a procurement team after a detailed evaluation. However, this barrier does not show significant differences for the two types of good according to section 4.2.4.4, further research for reasons is required.

The barrier variable of technological *utility* represents two barrier items. Both were evaluated in form of disagreement. The results show considerable disagreement with the barrier item about not exceeding measurable specifications of the older technology (T_Utlty_M) in contrast to the findings of Roure and Keeley (1990). The reason for a minor importance of the barrier may be the evolutionary tendency of providing high-tech innovation. Technology-intensive industries mostly present new technologies with higher performance than an older technology, mostly as sustaining innovation (see section 2.1.2). The utility of the new technology is usually better than the older. The new technology would than exceed the technical specification of the older technology, but additional research is required regarding the reasons for this finding of disagreement.

The problem that a new technology's utility is perceived to be less than the older technology's utility (T_Utlty_IC) is not seen as important by most of the respondents. This observation is in contrast to the findings regarding a value barrier of Ram and Sheth (1989), Hess (2009) and De Ruyter et al. (2001) and the findings of MacVaugh and Schiavone (2010) and related literature (Zeithaml, 1988; Davis, 1989, Moore & Benbasat, 1991).

For both barrier items of the model variable of *utility*, no significant differences for the two types of good are shown according to section 4.2.4.4. However, significant differences are illustrated for the different industries according to section 4.2.4.3, yet with negative agreements on the barrier items. However, further research is required to explore the reasons for these findings.

Referring to the LF-model, most barrier items of different variables are regarded to be important and occur with an empirical evidence of their existence in the perception of the participants of the survey. Apart from the barrier items that originate from the LF-model, additional barrier items are tested as well. Only one of those barrier items is evaluated with disagreement. That a technology is not adaptable to community constraints is not seen as very relevant or important barrier. Nevertheless, this barrier may be important in specific industries, as the tendency results for the pharmaceutics and biotech as examples show (see Table K-15).

5.2.1.2 Barrier variables and central tendencies

Apart from the barrier items, the LF-model variables are also evaluated by the tests of central tendencies. As they are constituted by the subordinate barrier items, the results are similar to the results described in the previous section.

The technology's *complexity* (T_Cmplx) and *complementarity* (T_Cmplm) are regarded as very important barrier variables. These findings support the structural findings of MacVaugh and Schiavone (2010) and the findings on complementarity and compatibility as important innovation attributes of Rogers (2003).

The *contagion* of the social structure (S_Cntgn) can also be listed as important barrier variable and supports the structural findings of MacVaugh and Schiavone (2010) and those of the chasm phenomenon (Moore, 2006). Subordinate barrier items are discussed earlier in the previous section.

The *cost of learning* (L_CstLrn) can as well be listed as important barrier variable with the agreement of the respondents, supporting the structural findings of MacVaugh and Schiavone (2010). The findings of the subordinate barrier items support the findings of Shapiro and Varian (1998) and Moreau et al. (2001) on a micro- and meso-level and Fornell (1992) on a macro-level of an industry/market.

Unlike the mentioned variables, technology *utility* (T_Utlty) is not agreed on as barrier variable in contrast to the findings about relative advantage as critical innovation attribute of Rogers (2003) and the structural findings of MacVaugh and Schiavone (2010). Subordinate barrier items are also discussed earlier in this section.

5.2.1.3 Generalisation of the perception of barriers via central tendencies

The results discussed in this section represent a generalization approach for technology-intensive industries. According to MacVaugh and Schiavone (2010), the barriers of the LF-model are context-dependent. Following the research objective of finding patterns of barriers and to provide a framework for practitioners, additional tendency tests are performed for sufficiently big subsample sizes. The barrier items are evaluated with different importance and relevance in the perception of survey participants depending on the industrial context, as the illustrations on the frequencies of agreement (see Figure Q-1 to Figure Q-13) show. Details on variations are discussed as part of the following section.

Following the first research objective of identifying important barriers for the diffusion of innovation from today's point of view, a comprehensive list of barrier items is researched and the perception of practitioners regarding their importance and relevance is presented as findings. The findings show that the reasons for non-adoption of a new technology can be diverse. Following the second research objective via hypothesis H1, variations among barriers are researched and differences in importance and relevance in the perception of practitioners are presented. The findings present the barrier items as part of the theoretical LF-model and according variations based on empirical data. The implication of the presented results is to increase the awareness for the importance and potential existence of diffusion barriers in technology-intensive industries. Following the third research objective, the findings can be used to provide a framework to guide practitioners during decision-making.

While with the findings of this section variations among barrier items are discussed, further variations, which depend on the context (e.g. of the industry or the economic region), are discussed in the following section.

5.2.2 Contextual variations of diffusion of innovation barriers

5.2.2.1 The extent of industrialization in the context of economic regions

As there are barely any variations due to different experience, education or job roles of the respondents (Appendix L), the set of answers concerning agreement on barrier importance can be regarded as a common understanding. In contrast to that, the results show variations on other criteria. Variation tests show that some barrier items show significant differences with subgroups of economic regions, different industries and different types of goods. Similarly, the barrier variables, which are composed of the barrier items, show variations. The discussion of variations focuses on barrier variables, but an overview is also given for barrier items, as they are presented and illustrated regarding their frequencies of agreements in section 4.2.4.

There are ten barrier items that show significant differences for emerging or developed countries. The majority of barrier items that vary in their perception depending on the economic regions constitute to barrier variables of social structure conditions (*social context*, *environmental awareness* and *contagion*). As emerging countries have a different cultural context as industrialised countries, the findings of variations support those of Jain and Maesincee (1998) and Asikainen et al. (2004). Significantly more participants of emerging countries agree on the three barrier items of the barrier variable *social context* (S_Cntxt) than participants of developed countries. As *social context* represents different problems in accessing a technology, this finding may be explained by less developed infrastructures and education systems.

Referring to the results of section 4.2.4.2, the differences of all barrier items show the tendency of a higher agreement on their importance and relevance by respondents from emerging countries. The variation in the participants' perceptions may be explained by higher fears of failure in emerging countries as developed countries are economically more successful, but further research is required to explore the reasons for this pattern. A starting point can be an analysis of cultural differences and readiness for innovation (e.g. Rogers & Shoemaker, 1971; Suvit & Jain, 1998; Yeniyurt & Townsend, 2003; Van den Bulte & Stremersch, 2004).

As the barrier items constitute barrier variables, similar variations are shown for the according barrier variables. Apart from *social context* and *environmental awareness*, variation is presented with the *learning capacity* to get trained on a new technology (L_Cpcty) depending on the economic region. For the barrier variables, additional tests are performed to research the correlation with the variable for economic regions as an extent of industrialization. Additionally considering responses from developing countries, the findings show a negative correlation coefficient with a mostly very weak strength. This finding supports the findings discussed regarding significant differences and a tendency of the perception of a higher relevance and importance of barriers in emerging economies.

5.2.2.2 The context of different technology-intensive industries

With a focus on technology-intensive industries with a representative size of the sample subgroup, significant differences are shown for eight barrier items. The findings of the context-dependency with the industrial context support the findings of MacVaugh and Schiavone (2010). The majority of the significant variations of barrier items are part of the social structure conditions of the LF-model. This finding may exist because each industry has its own social structure characteristics with a different extent of interaction and communication among potential adopters as community of users and different market players. All barrier items of the barrier variable *social context* show significant differences among the industries, as between medical and IT industry (compare with section 4.2.4.3).

An interesting result is the variation of the barrier item regarding the complementarity of a technology from a macro-perspective (T_Cmplm_M). Major differences are shown between the consumer electronics industry and other industries such as aeronautics, chemicals or pharmaceutical. This may be explained by a different length of the product life cycle, which for electronic consumer goods is very short. Other industries have a longer product life (such as an aeroplane) and the dominant design of corresponding industrial goods is difficult to be replaced. Further research can be performed regarding this proposition.

Two barrier items with variations due to the industrial context are candidates for extending the LF-model (S_EnvAw_I and T_Adptb_M). The barrier item which constitutes to the barrier variable of *adaptability* shows agreement for the medical industry (see Table K-12) whereas respondents from other industries regard the barrier as not being important (compare with section 4.2.4.3). This finding supports those of Petkova et al. (2010). A reason for this finding may be that medical equipment with its use on the human being need to be able to operate wherever people live, while other technological equipment (e.g. for electric/electronic manufacturing) may only be used in industrialized, rural area.

The other barrier item, the individual perception of environmentally-friendliness, shows disagreement for the industries of electric/electronic manufacturing (see Table K-10) and chemicals (see Table K-8), whereas a neutral evaluation is given by respondents in other industries (compare with section 4.2.4.3). In those industries environmental aspects may be more regulated than in other industries and therefore, the diffusion barriers may be less important or irrelevant. All barrier items of the *environmental awareness* with variations show different relevance depending on the industrial context.

The evaluation of barrier variables evolves that the variables of *social context* (S_Cntxt) and *adaptability* (T_Adptb) show significant differences and more variances among the industries than other variables (see Table M-10). The findings for *social context* support those of MacVaugh and Schiavone (2010) as well as Rogers (1963) regarding context-dependency. It seems that the barrier aspects of the variable of *adaptability* are perceived quite differently by the different industries. A reason for this may be that in some industries, it is common understanding that certain adaptability is provided, which is in contrast to the findings of Petkova et al. (2010).

The results of barrier items and barrier variables can be explained tentatively and industry by industry but this would go beyond the scope of this investigation. Therefore, additional research would be needed. A starting point can be the consideration of differences between levels of technology-intensity. Therefore, the findings are presented as generalisation for technology-intensive high- and medium high-tech industries (see section 4.2.3.1, Table K-2 or Figure 4-11). However, according to MacVaugh and Schiavone (2010) the barriers should be evaluated depending on the context of the industrial environment. Additionally, visual illustrations are provided to guide practitioners with the evaluation of the importance and relevance of barriers in their industrial context (see Appendix Q).

5.2.2.3 Different context between industrial and consumer goods

Depending on the type of good, five barriers are perceived with significantly different strengths of agreement. For example see more respondents working with industrial goods than with consumer goods the problem of not achieving a dominant design within the industry (T_CmpIm_M), which supports the proposition explained in the previous section regarding a long product life cycle of industrial goods. This finding supports the findings of Abernathy and Utterback (2003) and Rogers (1995). The example of costs of learning and switching (L_CstLrn_IC) may be explained by the characteristics of industrial goods as being a big investment with a profound amortisation calculation of the adopting organisation. This finding supports those of Shapiro and Varian (1998).

Similarly to barrier items, the variables of technology *complementarity* (T_CmpIm), *social context* (S_Cntxt) and *environmental awareness* (S_EnvAw) show as well significant differences. The findings of variation support the context-dependency of the LF-model with the findings of MacVaugh and Schiavone (2010). The barrier variable of technology complementarity is perceived to be more important for industrial goods. This maybe because of the importance of complementarity in production processes, in which a new technology is introduced as investment good in comparison to consumer goods, which often are stand-alone applications such as washing machines. The barrier variable of *social context* is perceived as being less important for industrial goods; a potential explanation can be that industrial goods are probably used in industrialized areas, in which access is provided.

The barrier variable for *environmental awareness* (S_EnvAw) is evaluated to be less important for industrial goods. This finding may be explained by the process of decision-making. Industrial goods tend to be big investments, which need to pay off. Calculations for their amortization are performed in detail and decision-making only focuses on environmental-friendliness if it comes along with convincing economic factors or mandatory sovereign regulations and laws. In contrast to rational decision-making of organizations, the environmental awareness of individuals may have more impact for the adoption-decision of consumer goods. Therefore more importance is given to barrier items by respondents working with consumer goods. The variations due to the type of good may be due to different reasons, for which further research is required.

5.2.2.4 Existence of variations and importance of context-dependency

The findings together with the details in the appendices show that there exist variations among the importance evaluations of the barrier items regarding economic region, type of good and industries. The barrier items constituting to the *social context* variable show variations for all three test series on significant differences. This finding emphasises the findings of Rogers (1983) and MacVaugh and Schiavone (2010) regarding context-dependency.

Due to the existence of variations, a list of barriers ordered by their importance (in the perception of respondents) as generalization may not be useful. The existence and importance of different barriers varies depending on aspects such as the type of good or the industry into which the new technology is going to be introduced. An analysis of which barriers need to be considered in decision-making may be necessary for each technology individually and even at different points in time (see section 2.1.4).

Following the second research objective via hypothesis H1, variations between barriers are researched and differences in the participants' perception of importance and relevance are presented. The presented findings imply to focus on the context when assessing potential barriers. Following a further research objective, the findings with a focus on industry differences are used to provide a framework for practitioners.

The discussed results not only show variations for barrier items originating from the LF-model, but also additionally tested barrier items. In order to evaluate whether additionally tested barrier items are generalizable and can extend the LF-model as framework, the results of several suitable tests are discussed as follows.

5.2.3 Testing the suggestions of LF-model modifications

5.2.3.1 Improvement of internal model consistency with modifications

As a finding of the cluster analysis from the qualitative research, an additional barrier item is presented for the LF-model describing ‘missing inter-industrial collaboration’ as a barrier. Findings in literature support the results of the case study research regarding this problem for the media industry of digital radio (Goldhammer et al., 2008) and similar findings by Margolis and Zuboy (2006) for solar energy technologies. As a consequence, a complimentary modification of the LF-model is suggested according to the scheme of Figure 5-1 and the resulting model illustrated by Table Q-2.

The critical diffusion aspect of a needed *adaptability* for a technology are also mentioned in literature (Berman & McLaughlin, 1977; Wolfe, 1994; Rogers, 1995; Richerson, 2001; Nutle et al., 2002; Petkova et al., 2010; Steinheber & Chlupsa, 2012). Although not identified as a barrier cluster, a comparable cluster evolved with the need for upgradeability in the case study research.

Similarly, a cluster evolves describing that a new technology is not perceived to be green. Our society demonstrates a higher *environmental awareness* as the explanations in section 2.4.3.3 show and related aspects can have the effect of a barrier (Peattie & Crane, 2005).

Another cluster from qualitative research describes potential leapfrogging with the anticipated availability of mobile internet technologies that are even better. The aspects described are part of the critical evaluation of limitations of the LF-model (see section 2.4.3). Barriers of these topics seem not be represented by the LF-model.

Therefore, several barrier items as potential modifications of the LF-model are researched by the survey and verified with different tests. Most test results turn out to be supporting the modifications of the LF-model. The subjects for modification are two additional barrier variables and the LF-model variable of *orientations*. The barrier variables of *adaptability* and *environmental awareness* are suggested, having three subordinate barrier items each. For the LF-model variable of *orientations*, the integration of an additional barrier item for the market/industry domain and the rewording of the barrier item of the community domain (considering an even better technology) are suggested. As the LF-model is based on the assumption of utility-maximizing related to the adoption of a new technology; suitable wordings were suggested as described in section 3.4.2.1 to explore potential modifications (marked in grey in Figure 5-2) according to the following scheme (Figure 5-2).

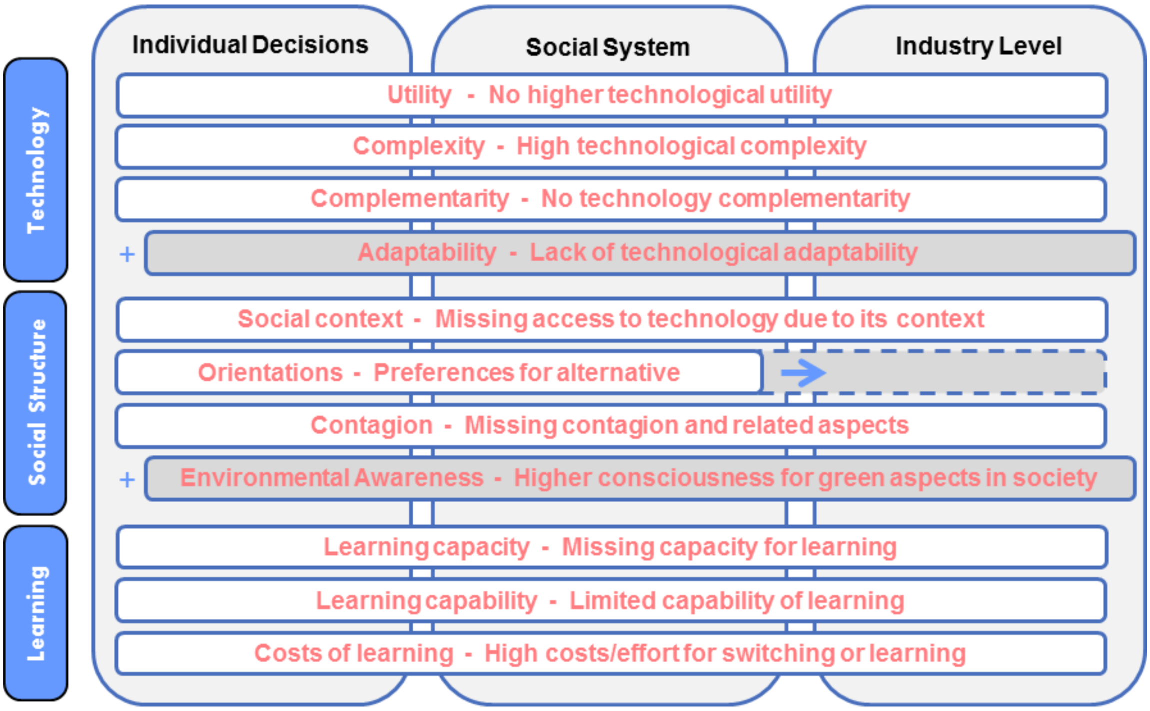


Figure 5-2 – Extension and modification of LF-model (scheme)

Following the research objective of identifying the relevant and most important barriers for diffusion of innovation and the objective of providing a framework for practitioners, the test results regarding potential modifications are discussed in the following sections.

5.2.3.2 Internal model consistency with modifications and related model structure

Tests of reliability and internal consistency were conducted via Cronbach's α with the statements representing the barrier items of the LF-model, the seven additional barrier item statements and one alternative wording for barrier item of the LF-model. Most of the suggested modifications, which are tested separately, result in a higher α-value.

The resulting α-value of the entire model using the alternative wording (S_Orntn_C2, considering an even newer technology under discussion) for the barrier item of *orientations* in the community domain is smaller than the value of the original LF-model. Furthermore, the results of central tendencies as generalisation show similar agreements between the barrier item originating from the LF-model and the reworded version. With a weaker internal consistence, this suggested modification was withdrawn.

All results were confirmed by the reliability tests performed for the groups of barrier items describing the according conditions (technology and social structure). The result of higher internal consistency may occur as mostly barrier items were added, which supports the findings of Gulliksen (1950). Therefore, other tests were conducted in addition to those for internal consistency. However, the results prove a higher reliability of the model with most changes suggested.

As no useful model structure of good readability is identified by factor or principle component analysis (see section 3.4.5.5) and the model structure of the LF-model of MacVaugh and Schiavone (2010) seems to provide a profound and readable framework (Steinheber, 2014), its basic structure is suggested to be applied and no conceptual modification is suggested. The operationalised statements used to represent the additional barrier items in the survey are transformed to match the textual wording of the LF-model. With the existing model structure and the transformed texts, a possible modification of the LF-model can be illustrated in grey colour within the following table (Table 5-1).

<table>
<tr><th colspan="3" rowspan="2">New technology fails to replace older (or no use of) technology when …</th><th colspan="3">In the domain of the:</th></tr>
<tr><th>Individual User</th><th>Community of Users</th><th>Market / Industry</th></tr>
<tr><td rowspan="13">Given the effect of conditions relating to:</td><td rowspan="4">Technology</td><td>… utility …</td><td colspan="2">… is perceived to be less than the older technology</td><td>… fails to exceed the older technology's measurable specifications</td></tr>
<tr><td>… complexity …</td><td colspan="2">… focuses attention on overall effectiveness not newest feature</td><td>… renders really new innovation less frequent</td></tr>
<tr><td>… complementarity …</td><td colspan="2">… of older technology results in higher total utility</td><td>… does not lead to a dominant design</td></tr>
<tr><td>… adaptability …</td><td>… is not perceived to support changes / upgrades to satisfy future needs</td><td>… does not support local modifications by efforts within a community</td><td>… does not allow the usage for a number of different applications and markets</td></tr>
<tr><td rowspan="4">Social Structure</td><td>… context …</td><td>… creates material limits to access</td><td>… supports social divisions to access</td><td>… restricts access on behalf of proprietors / the state</td></tr>
<tr><td>… orientations …</td><td>… towards its use are negative</td><td>… are towards the older technology</td><td>… of one industry is not supporting inter-industrial collaboration to develop the market</td></tr>
<tr><td>… contagion …</td><td colspan="2">… is not strong enough to displace existing community norms</td><td>… is not dispersed due to poor marketing and/or operations functionality</td></tr>
<tr><td>… environmental awareness …</td><td>… leads to individual perceptions that the new technology is not environmentally-friendly</td><td>… is not addressed by explaining aspects for sustainability in published form</td><td>… is exploited by exaggerating that the new technology is more environmentally-friendly</td></tr>
<tr><td rowspan="3">Learning</td><td>… capacity …</td><td>… or cognitive ability limits learning</td><td>… to access education is limited</td><td>… of resources / guidance is inadequate</td></tr>
<tr><td>… capability …</td><td>… generated by older product use does not assist in new technology use</td><td>… of users has not created a community of expertise</td><td>… to experience the product is diminished</td></tr>
<tr><td>… costs …</td><td colspan="2">… related to switching are high</td><td>… of learning determined by the product are prohibitive</td></tr>
</table>

Source: Adapted from MacVaugh and Schiavone (2010) and modified for the thesis

Table 5-1 – Possible modification of MacVaugh and Schiavone's LF-model

The barrier of 'missing inter-industrial collaboration' is regarded as the modification with the strongest evidence as it is presented as an important result of the case study research and the related literature. It contributes as barrier item (S_Orntn_M) to a higher model reliability by the outcomes of testing the survey.

5.2.3.3 Central tendency tests and generalisation with the suggested modifications

The modification of the barrier variable of *orientations* and the macro-level domain of an industry/market by adding the barrier item describing 'missing inter-industrial collaboration' is seen as a complementary contribution to the LF-model of MacVaugh and Schiavone (2010). Therefore, it is suggested to be incorporated into the LF-model with the wording '… of one industry is not supporting inter-industrial collaboration to develop the market' as explained in the sections 4.1.3.6, 4.1.6 and 5.1.3. The result of testing central tendencies for generalization does not show any disagreement with this barrier item. However, respondents of some industries consider the barrier as more important than others.

The tests for generalization via central tendencies do not show disagreement with the other new barrier items as candidates either, except for the barrier item of *adaptability* as part of the community domain (T_Adptb_C). This finding is in contrast to those of Berman and McLaughlin (1977) and Petkova et al. (2010). This may be because of the industrial context, as in industries such as pharma & biotech; medical and automotive the barrier item is not strongly disagreed with. As in some industrial segments, the barrier item has more importance than in others, its relevance should be considered. With the need for allowing a re-design of technologies to fit regional constraints, an example can be given for medical industries (Petkova et al., 2010). The central tendency test of the barrier variable of adaptability with the sample of focus shows considerable agreement with the variable concerning its mode whereas its medium result is neutral (see Table K-3).

Two of three barrier items (S_EnvAw_C and S_EnvAw_M) that form the barrier variable of *environmental awareness* show agreement with considerable strength. This supports the findings of Peattie and Crane (2005). In contrast to that, individual perceptions of missing environmental friendliness of a technology (S_EnvAw_I) neither is agreed nor disagreed on. The findings support those of MacVaugh and Schiavone (2010) who argue that green aspects may not be the driving force for the adoption or non-adoption of a new technology. The tendency test of the barrier variable neither shows agreement nor disagreement (compare Table K-3) whereas the illustrations of frequencies of different agreement levels show its importance and relevance (compare Figure 4-13 to Figure 4-21).

5.2.3.4 Variation and correlation tests with the suggested modifications

Both, the generalization tests via central tendencies and the tests of variations are performed with the barrier items originating from the LF-model and the new barrier item candidates. Referring to presented results following hypothesis H1 (see sections 4.2.3 and 4.2.4), it can be outlined that all barriers including those that are suggested for modifying the LF-model show variations. These findings support those about context dependency by MacVaugh and Schiavone (2010) relating to the LF-model and by Rogers (1983) relating to generally influencing factors for diffusion.

The two suggested additional variables consist of subordinate barrier items, whose wording may be similar to other barrier items already existing in the LF-model. It could be criticized that aspects of the newly introduced barrier variables may already be covered by the LF-model. Therefore, the hypotheses H3 and H4 describe potential correlations. The strengths of those correlations are also compared with correlation results among the LF-model variables, applying hypothesis H2. The results with the LF-model variables show that all LF-model variables correlate with each other but with different strengths. The strongest correlation between *learning capability* (L_Cpblt) and *learning capacity* (L_Cpcty) has strength of more than 0.6 (see section 4.2.5.2). This may be because individual ability or insufficient capacity within an organization or the market/industry for learning (e.g. budget, information) affects the *learning capability*. Correlation results of the new barrier variables are compared with those of the LF-model.

The correlation results of the Spearman test show that there is a strong correlation of the introduced barrier variable adaptability and a technology's *utility* (T_Utlty). Other

LF-model variables (T_Cmplx and T_Cmplm) show medium strong correlations with *adaptability*. A technology's *utility* may be the most comparable variable to the technology's *adaptability* within the LF-model. The ability of adapting a new technology for personal needs and due to community constraints may be perceived as a higher utility. Nevertheless, stating according barriers separately as additional level of influence in the LF-model may be valid, as the relative strength of the correlation compared with the strengths of other LF-model variables is not much higher.

Similarly show the results of the Spearman correlation test that there is a medium strong correlation between the introduced barrier variable of *environmental awareness* and the LF-model variable of *social context*. Depending on the cultural context as for example in different countries, the *environmental awareness* of the population may look very differently. Another reason for the correlation strength may be that the variable *social context* describes the access to a technology for different domains. The barrier items of *environmental awareness* describe the access of information about sustainability and environmental-friendliness. However, comparable correlations can also be shown with other barrier variables of the LF-model (e.g. T_Utlty or S_Orntn). Focusing on correlation results, the additional barrier variable may be incorporated into the LF-model of MacVaugh and Schiavone (2010). However, the importance of environmental awareness and green aspects of a technology are evaluated by the authors of the LF-model to be unimportant (MacVaugh & Schiavone, 2010).

Following the first and the third research objective, the potential modifications with new barrier items are tested as part of the survey analysis via reliability analysis, central tendencies, variations and also correlations. The survey results show no strong confirmation of their importance and relevance, but also no strong disagreement is identified (in contrast to the variable of technology *utility*). The availability of an even better technology describing leap-frogging as alternative barrier item to the one as part of the LF-model was withdrawn due to a reduced internal consistency.

Following the research objective of suggesting a framework for practitioners, the findings imply that potential modifications of the LF-model should be selected carefully. With a main emphasis on the approach of mixed-methods and triangulation between the different types of gathered data and theoretical references, not all suggested modifications may be considered due to differing theoretical and empirical evidence. The following section presents the integration of the case study research and survey results under triangulation aspects of the mixed-methods approach.

5.3 Discussion of integrating results due to mixed-methods approach

Referring to the LF-model, several barrier items (contributing to different barrier variables) occur with an empirical evidence of their importance and relevance due to either the qualitative or quantitative research. Following a mixed-methods approach, the discussion of integrating findings from both methods is subject to this section.

The integration of results regarding the barriers emerging from the case study research and their confirmation via the quantitative survey approach are presented in section 4.3. The data of both approaches is integrated and compared. Following the first and third research objective, the finding of the barrier describing a 'missing inter-industrial collaboration' is confirmed and was therefore suggested to be integrated into the LF-model (see Table Q-2). For the integration of other findings from the quantitative survey following a mixed-methods approach, some aspects need to be taken into account.

Following the research objective of identifying further important diffusion barriers, the qualitative data was consolidated in order to create new barrier variables which are considered for different modifications of the LF-model (see section 5.1.3). The test results regarding modifications are discussed in section 5.2.3. Consequently, the trustworthiness of both, qualitative and quantitative data is assessed (Migiro & Magangi, 2011) for integrating the different results into a suitable framework for practitioners.

As several figures illustrate, the LF-model of MacVaugh and Schiavone (2010) provides a compound basis as framework due to its focus on industry practitioners and its profound basis of supporting findings. Following the third research objective, the LF-model is used as framework of barriers to be directed to practitioners. As it relates to the replacement of old technology or non-adoption of new technology based on adopters' attempt of utility-maximizing, it seems especially suitable for technology-intensive industries and investment goods.

The *environmental awareness* of society is suggested to be integrated into the LF-model as variable (S_EnvAw) with subordinate barrier items. The new variable may correlate with variables of the social structure as described. MacVaugh and Schiavone (2010) allocate green aspects to technology conditions which is also supported by other publications (Tischner et al., 2000; Attari et al., 2010; Kumar, 2010; Steinheber & Gerstl, 2012). Furthermore, proprietary constraints (ISO, 2011, 2012; Steinheber, 2012) may be important. Others might describe environmental awareness as a temporary trend in a social environment (Stern, 1999; Vandenbergh et al., 2011). Regarding the attempt of potential adopters of utility-maximizing as assumption for the LF-model (MacVaugh & Schiavone, 2010), the modification may be questionable. With a higher environmental awareness in our society, green marketing (without green washing) can be a facilitator (Cronin et al., 2011) but also a barrier if potential adopters get suspicious and show a backlash (Peattie & Crane, 2005).

While the qualitative research did not evolve such aspects as relevant diffusion barriers, the quantitative research does show a considerable agreement with some related barrier items (in contrast to the barrier items of the variable of technology *utility*). The variation results show that the barriers are regarded as less important for industrial goods and more important for consumer goods. The results also show a certain tendency for its correlation with the *social context* within a social structure. The research findings would need to be supported by further findings of research relating to non-adoption due to environmental awareness aspects. The following fragment (Table 5-2) illustrates this by the grey cells.

		… environmental awareness ...	… leads to individual perceptions that the new technology is not environmentally-friendly *(…)*	… is not addressed by explaining aspects for sustainability in published form *(…)*	… is exploited by exaggerating that the new technology is more environmentally-friendly *(Peattie & Crane, 2005)*

Table 5-2 – Fragment for LF-model extension by environmental awareness

The fragment shows the need for further supporting literature mentioning non-adoption for two barrier items (in the domains of individual and the community of users), which can be subject for further research.

In conclusion, certain agreement by the survey, but a lack of evidence from case study research results and missing evidence of further literature regarding its reason for non-adoption show a deficiency of triangulation. As the authors of the LF-model disregard green aspects and assume utility-maximizing for the LF-model, an insertion into the LF-model is questionable. Considering the different argumentations presented, the variable of *environmental awareness* is regarded as extension of the LF-model with weak evidence. However, with its integration a higher internal consistence can be outlined (see section 4.2.6).

In contrast to *environmental awareness*, technological *adaptability* as the other suggested new LF-model variable (S_EnvAw) may be in line with the assumption for utility-maximizing. Especially with the demands and perceptions of adaptability by a new generation (Steinheber & Chlupsa, 2012), technologies need to provide possibilities for upgrades and modifications (Berman & McLaughlin, 1977; Wolfe, 1994; Richerson, 2001; Bardhan & Chanda, 2007). Years after Rogers' initial publications about diffusion of innovation (Rogers, 1962) and criticism on missing adaptability, the author considers re-invention as the possibility for a potential adopter of modifying the innovation (Rogers, 1995). The case study research results show that adaptability is mentioned as being important whereas it is not seen as barrier for the diffusion of digital radio in the German industry and market. However, other findings show the existence of such a barrier as reason for non-adoption, e.g. for the medical industry (Petkova et al., 2010). Although one subordinate statement for *adaptability* is not agreed on by the survey respondents of technology-intensive industries, the barrier variable shows a slight agreement (see Table K-3). In some industries the barrier variable shows a considerable level of agreement, as in pharma & biotech (see section 4.2.4.3 and Figure 4-20) and medical industries (see Figure 4-19).

Considering no clear and only considerable agreement by the survey and the absence of strong evidence by the case study research, a sufficient triangulation regarding a mixed-methods approach is not achieved. Additionally, the barrier variable tends to correlate with the variable for technology's *utility*. However, considering further literature mentioning non-adoption (e.g. Petkova et al., 2010) and the suitability with the utility-maximizing assumption for the LF-model, the variable is regarded as extension of the LF-model with minor evidence. However, with its integration a higher internal consistence can be outlined (see section 4.2.6). The integration of an additional row in the table describing the LF-model looks as follows (Table 5-3) with a grey cell indicating the need for further research findings to support the insertion.

		… adaptability …	… is not perceived to support changes / upgrades to satisfy future needs. *(Wolfe, 1994; Rogers, 1995; Steinheber & Chlupsa, 2012)*	… does not support local modifications by efforts within a community *(Berman & McLaughlin, 1977; Petkova et al., 2010)*	… does not allow the usage for a number of different applications and markets (…)

Table 5-3 – Fragment for LF-model extension by technology adaptability

The fragment shows a grey cell due to a lack of literature references, which may describe this barrier item for the market/industry domain mentioning non-adoption. This can be subject for further research. Thus, the complete barrier variable is not incorporated into the final framework.

In contrast to the discussed modifications, the barrier aspect of a 'missing inter-industrial collaboration' (S_Orntn_M) shows multiple evidences. The findings are supported by those of Margolis and Zuboy (2006), Goldhammer et al. (2010) and Anderson (2013). Besides theoretical evidence, empirical evidence is provided by qualitative and quantitative research as a mixed-methods approach. With the benefit of triangulation as an advantage of a mixed-methods approach together with references to literature, this barrier item is presented with high evidence. The barrier item of 'missing inter-industrial collaboration' fills the blank position for the market/industry domain of the *orientations* variable of the LF-model with a suitable wording as section 5.1 shows referring to Table Q-2. So far there has been a grey empty spot in the LF-model of MacVaugh and Schiavone (2010). The authors of the LF-model leave this aspect blank, because in their opinion a market/industry by definition needs to have a positive orientation towards a technology as the following note attached to their LF-model shows.

*"Note**:** The dark grey box indicates that, historically, a competitive market/industry has ususally been oriented towards innovation diffusion"*

(MacVaugh & Schiavone, 2010, p. 208)

The authors explain that with profit-making as driving force an industry would be oriented towards a technology (MacVaugh, 2012). But a technology can be subject for more than one industry, such as with digital radio as an example for a network industry with a need for infrastructure. One industry might not be eager for a market with the technology but its collaboration with other industries would be needed for the creation of a market and the introduction of a technology. This lack of collaboration, illustrated in section 2.4.3.4 is regarded as barrier limiting the diffusion of innovation. The orientation of a whole industry is now considered in the modified framework contributing to the *orientations* variable (Table Q-2).

This finding from case study research is confirmed by the survey, as the sample of the according industry shows agreement with the barrier item. No disagreement is shown in a generalization approach with technology-intensive industries. The integration of this barrier into the framework based on the LF-model provides sufficient triangulation. Therefore, the grey spot of the LF-model is filled with the barrier description for 'missing inter-industrial collaboration' and supporting literature, as Table Q-2 illustrates.

Following the first and third research objective, findings of different empirical evidence and triangulation are presented. While the findings can be presented as a framework with strong evidence (See Table Q-2), an additional form of presentation is illustrated with weaker evidence considering the fragment for *environmental awareness* (Table 5-2) and the fragment for *adaptability* (Table 5-3). In the presented resulting framework, these aspects are attached as a note to advice practitioners of these potential diffusion challenges (see Table Q-2). The literature list, supporting the LF-model (MacVaugh & Schiavone, 2010, pp. 210-215), is extended similarly by further literature supporting the introduced barriers and the barrier concepts compared with the LF-model for further research (see Table Q-1).

In addition to the framework results, visual illustrations are available for all barrier items including those of the variables *adaptability* and *environmental awareness*, representing the frequency of agreements of practitioners in the industry context (see Figure Q-1 to Figure Q-13). Following the research objectives, the use of the framework together with these graphical weighting schemes can guide practitioners in decision-making regarding the importance and potential existence of diffusion barriers. The discussed results are briefly summarized in the next section.

5.4 Summary of the discussion and integration of results

Within this chapter, empiric results of the case study research and the survey are discussed and integrated following the mixed-methods approach. Patterns of variations among relevant contemporary diffusion barriers are presented as findings following the first research objective and a framework for practitioners is presented together with graphical weighting schemes.

Regarding the case study research, some barriers of the LF-model are presented with strong evidence. Missing inter-industrial collaboration as an additional barrier is suggested to fill an existing gap in the LF-model. Further aspects related to the *adaptability* and *environmental awareness* as potential modifications are also discussed.

The results of the survey with operationalised barrier items show context-dependant variations regarding the perception of the importance and relevance of both, barriers originating from the LF-model and additional barriers. The variation results support the second research objective. The barriers are discussed regarding their adequacy of supporting other findings like those of Moore (2006). Besides a general barrier pattern, a major finding is the context-dependency of barriers for diffusion of innovation, supporting those of Rogers (1983) and MacVaugh and Schiavone (2010).

The integration of the different findings of the mixed-methods approach results in a framework for practitioners, which is mainly based on the LF-model. The framework contains the LF-model modification of an additional barrier (describing ‘missing inter-industrial collaboration’), which represents a finding with strong evidence. Considering triangulation, the suggested modifications of the LF-model are evaluated regarding supporting literature and empirical evidences. Being of weaker evidence, possible additional fragments for the extension of the LF-model by the variables of *adaptability* and *environmental awareness* are presented. Because of the context-dependency and the described evidence, it is suggested to use the presented framework (Table Q-2) as basic orientation together with industry-dependent weighting schemes (Appendix Q) in order to analyse the existence of potential barriers for a new technology. The resulting framework serves the third research objective.

Following the research objectives, this chapter has discussed the existence and relevance of contemporary barriers for diffusion of innovation, their context-dependency via variations and how the findings result in a framework for practitioners. The next, final chapter presents conclusions, limitations and implications for the discussed results.

6. Conclusion

This final chapter draws conclusions for the discussed results. Key findings are summarized and contribution to knowledge regarding methodology, practice and theory is explained. Limitations of the research are outlined and suggestions for further research are given. As one research objective is to provide an outcome for people working in technology sales and marketing, implications to practice are described.

6.1 Preliminary remark on the research area

Prior to final words about key findings and major conclusions, this section should help to recall the main research area and objectives of the research. As literature about diffusion of innovation is rather focused on facilitating aspects, this research focuses on barriers. A lot of innovations seem to fail on the market and this study questions why the diffusion of innovation struggles and new technologies are not adopted.

Many existing concepts of diffusion barriers are mostly theoretical, referring to findings from different industries from past decades. Other findings seem to be limited as they focus on individual decision-making and do not consider macro-level aspects. Some gaps in diffusion of innovation knowledge were identified regarding the context of today and the occurrence of multiple barriers depending on the industry.

The aim of this research has been to identify contemporary relevant and important diffusion barriers for technology-intensive manufacturing industries. With the reference of the LF-model, the barriers are researched regarding variances and patterns. Another research objective was the ambition to put theory into practice by providing a tailored framework for practitioners as a guideline for decision-making.

Key research findings of a mixed-methods approach via the research of a unique case and an online survey, the contribution to knowledge and the research limitations and implications for those challenging barriers are presented in the following sections.

6.2 Summary of key findings and conclusion

6.2.1 Objective 1 - Identification of contemporary diffusion barriers

Based on investigations of diffusion barriers of the last decades and their outcomes, an overview on the existence of very different barriers is given by the literature research. Different concepts of barriers are compared focusing on adoption decisions of individuals, within the community and market/industry constraints. The findings of MacVaugh and Schiavone (2010) provide a suitable framework for reference. In order to address the objective of identifying important barriers for the diffusion of an innovation, mixed methods were used.

Both a survey and a case study research show with empirical evidence the existence and co-existence of a variety of barriers hindering new technology to diffuse into the market. The LF-model of MacVaugh and Schiavone (2010) served as a basis as it is very profound and compounds various conditions as well as micro-, meso- and macro-domains.

The findings of the qualitative research of the diffusion of digital radio in Germany as a very unique case show that a diversity of barriers can occur. The findings show that the introduction of digital radio technology as subject to replace FM, one of the oldest analogue technologies in place, has failed and no strong diffusion has been taking place in Germany. Cluster analysis deduced a diversity of interrelated barriers from interviews with stakeholders along the value chain. Most of the barriers could be identified in the LF-model. With a ‘missing inter-industrial collaboration’, an additional barrier was identified, verified and confirmed by survey analysis. It contributes to the theoretical LF-model as a complementary finding as it adds to a limited literature.

Apart from diffusion barriers, problematic aspects regarding technological adaptability, internet dominance and environmental awareness of society emerged from the qualitative analysis. Following the first research objective, these potential diffusion challenges, the new identified barriers and the barriers originating from the LF-model were the basis for quantitative survey research.

While the LF-model refers to barriers by citing publications, which are specific for a concrete case or industry, the survey was directed to practitioners from very different industries via a professional social network. To achieve a high representativeness of the survey, measures were taken to address the experienced population in manufacturing industries with a high technology-intensity.

Thus, empirical data on the importance and relevance of barriers in the perception of practitioners could be gathered. An approach for generalization for all technology-intensive industries is presented. These findings support most barriers identified by MacVaugh and Schiavone (2010). However, many participants do not perceive technological utility and its perception by potential adopters as important barriers, which is in contrast to the case study research results. Other barrier items of the LF-model, such as a lack of marketing and high technological complexity from a macro perspective, are perceived as very important. The suggested barrier describing ‘missing inter-industrial collaboration’ and additional barriers regarding the variables of *adaptability* and *environmental awareness* as potential modification of the model are perceived to be more important than barrier aspects of the *utility* variable of the LF-model. Apart from utility, all barriers that evolved from case study research could be confirmed by the according industry subgroup of the survey.

The hypothesis describing the existence of variations among a list of different barriers (H1) is confirmed by both a case study and survey research. As the findings of the survey show, some barriers seem to be more important than others. The authors of the LF-model explain this with a strong context-dependency. The variations are not only researched regarding their perceived importance and relevance but also regarding differences depending on the context of different industries, different economic areas and different types of goods.

6.2.2 Objective 2 - Variations and patterns of diffusion barriers in context

Besides the existence of several barriers today, another objective of the research was to investigate variations, interdependencies and patterns of barriers. The previous section mentions variations in the perception of the barriers regarding their importance by respondents of the survey. In contrast to the survey, the case study research reveals that the most important barrier for the diffusion of digital radio was that the new technology was not perceived to provide a higher utility. The importance of diffusion barriers not only varies among the barriers but also depending on the context of an industry, the economic environment of a region or the type of good.

The main method of addressing this research objective was via a survey research and according hypotheses. Hypothesis H1 and according sub-hypotheses were used to research variations of barrier variables and subordinate barrier items. Furthermore, hypotheses H2, H3 and H4 were used to verify correlations of barrier variables.

The results of the survey reveal variations among the barriers regarding their importance and existence in the perception of the participants via the observation of central tendencies. Significant differences of some barriers are illustrated for technology-intensive industries but also depending on the economic region and the type of good. Several industry subgroups of the sample show a different pattern of agreement with the barriers. Respondents to the survey from emerging countries tend to give barriers a higher importance than in developed countries. While the importance and relevance of most barriers is similar or quite comparable among the different high-tech industries, some barriers show significant variations. There are also variations for some barriers between industrial and consumer goods. The observations show differences in the importance depending on the context, which support the findings of MacVaugh and Schiavone (2010).

The description of resulting barrier clusters from the qualitative research illustrates that diffusion barriers for digital radio show some interdependencies. However, correlations are mainly researched by a survey analysis. According to correlation tests, all researched LF-model variables correlate with different strengths. Some barriers correlate more than others. Similarly, the variables of the LF-model and additional barrier variables show correlations of different positive strengths.

With the findings of variations and tests of internal consistency and dependency, a suitable presentation of results is directed to practitioners. Focusing on the context of technology-intensive industries, a suitable framework concept is suggested to assist in decision-making.

6.2.3 Objective 3 - Tailoring of a practical framework of diffusion barriers

The motivation for this study is the phenomenon that a high percentage of newly introduced technologies fail on the market. Since this is a high risk for companies, practitioners in strategic decision-making positions should be aware of a diversity of challenges and barriers as the reasons why innovations can fail.

Therefore, one research objective was to provide a suitable framework of barriers to practitioners in order to assist with decision-making for new product development incorporating new technology and to prepare marketing methods in order to overcome diffusion barriers. One challenge described as a research question is how to successfully market a new innovation. With a provided framework, the awareness of potential diffusion barriers can be increased. As the success of an innovation and its diffusion strongly depend on the context, an evaluation of barriers has to be carried out for each new technology multiple times during the related integrated product life cycle. A suitable framework assists to do so.

A framework model as a modification of the integrated LF-model is the result of the mixed-methods approach. The strongest and most important finding of this research is a modification of the theoretical LF-model of barriers by closing a gap and adding the barrier of ‘missing inter-industrial collaboration’ based on multiple empirical data. The validity of the modification is checked and established by triangulation. With the research objective of suggesting a framework for practitioners, the modified integrated LF-model is presented (See Table Q-2).

Referring to the findings of the survey, further diffusion challenges regarding technological *adaptability* and *environmental awareness* are considered. As new model variables for the LF-model, the findings could also be integrated (see Table 5-2 and Table 5-3) but provide weaker validity through triangulation.

In addition to the model, illustrations of findings allow an increased understanding of the existence of barrier phenomena by practitioners. Evaluations of the importance and relevance of barriers are presented as weighting schemes (see Appendix Q) to allow a tailoring of the framework in the context of technology-intensive industries. Referring to the third research objective, these findings as a result of the survey can be used by practitioners (e.g. of technology marketing and sales) for strategic decision-making together with the developed framework model.

Practitioners benefit from the research in having an empirically tested framework of barriers, for which illustrations with context-dependant weightings of the importance and existence of barriers are additionally provided. Its application shall raise practitioners' awareness for the existence of barriers when introducing a new technology. History shows the existence of diffusion challenges for innovation. An increased awareness for barriers among practitioners is a broader implication from the results of this study, especially in marketing positions.

6.3 Contribution to knowledge

6.3.1 Methodological contribution

This research contributes to existing knowledge in the areas of methodology, theory and practice. Methodological contributions are made as part of the mixed-methods research approach. Both the qualitative and the quantitative research applied unusual but novel methods. For example, for qualitative research, mind mapping was applied. The technique seems not to be very common in academic research but its suitability in combination with data-recording and subscription is illustrated.

The strategy of community sampling for the online questionnaire considers the benefits of professional social networks. Apart from their continuously growing number of members implying importance in today's social and business life, the networks provide easy accessibility to people all over the world. The professional social network of LinkedIn was used to reach out to the target group of marketing and sales experts from all over the world. The main benefit of this sampling approach as a major methodological contribution was reach as the number of responses far exceeds one thousand (with 726 respondents as sample of focus). This approach seems to be unconventional in comparison to other sampling approaches but its use was very powerful for data gathering from very different industries and economic regions in order to study patterns among barriers for innovation.

The existing, theoretical LF-model is based on literature investigation and required quantitative study for verification. This research contributes to the methodology applied by MacVaugh and Schiavone (2010) as empirical data from a survey is provided for the barriers mentioned in the LF-model. Those and seven additional barrier aspects are evaluated by practitioners from different, mainly technology-intensive, industries. Most barriers are confirmed regarding their existence and importance. Furthermore, the empirical results show relations with different strengths among the barrier variables of the LF-model.

6.3.2 Theoretical contribution

In order to put things into practice, the LF-model as a theoretical concept is referred to and presented as a framework for practitioners in a modified form. The LF-model is based on theoretical references and provides a good structure and readability. Moreover, its usability is evaluated as being suitable due to its recent, profound base of references and its composition of dimensions with conditions and domains representing micro-, meso- and macro-levels of perspectives regarding players of interest.

By the mapping of challenging barrier clusters to the LF-model based on the case study research with digital radio, a contribution to new syntheses and analyses of existing knowledge to MacVaugh and Schiavone's LF-model (2010) is made. The LF-model seemed to show gaps when classifying barriers of the case study research. Problematic and challenging aspects, such as missing inter-industrial collaboration when introducing a new technology, are not reflected by the LF-model. Therefore, contribution is made to the LF-model. With the introduction of an additional barrier aspect to the LF-model, an existing gap is closed. The additional barrier is confirmed with empirical evidence from triangulation of literature and both methods from the mixed-methods research. It represents a strong finding of the research.

Referring to the first research objective, this is not the only barrier aspect identified. With a needed *adaptability* of a technology and an increased *environmental awareness* of society, two additional barrier variables are researched. Each consists of various barrier aspects. Both variables are suggested as model extension in form of two additional levels of influence. They are regarded as findings with a weaker validity referring to triangulation and further research may support them. However, their importance and relevance as diffusion challenges is pointed out for practitioners by illustrations supporting the LF-model and an additional note. The additional barrier of a missing inter-industrial collaboration is a stronger theoretical contribution to the LF-model.

The LF-model represents important reasons for non-adoption, each by one cell. However, the literature of the model does not explain how barriers may be related. Following the second research objective, the case study research describes interrelations of barriers (via barrier clusters and items) and the survey findings present correlations between the model variables of the LF-model and their strength. Overlapping effects of the different contexts and domains of the LF-model are described, which is considered as theoretical contribution to the findings of MacVaugh and Schiavone (2010).

With empirical data, differences in the importance and existence of barriers are outlined as different patterns according to the research objective. As MacVaugh and Schiavone (2010) explain the context dependency of the LF-model, variations are presented as different patterns distinguishing economic region, type of good and the areas of different industries. This information is provided as visualised weighting schemes for different industries contributing as a further component to the LF-model. In addition, a generalised framework is provided to practitioners following a major research objective. How the framework, the weighting schemes and the other results of the research can be used and put into practice is described in the next section.

6.3.3 Practical contribution

With the possibility of using the refined model, practitioners have a framework as a guideline to put theory into practice for decision-making. This follows the third research objective of the thesis. Apart from that, the practical contribution is based both on the results of the qualitative research and those of the quantitative research.

With the focus on the introduction of digital radio technology in Germany as case study research, challenges and barriers for its diffusion are researched with the participation of knowledgeable industry experts. The contribution to knowledge with empirical data allows stakeholders of countries other than Germany to evaluate the lessons-learnt for the introduction of a new technology in the broadcasting and media industry. The problems which occurred during the introduction of digital radio in Germany are illustrated as important barriers to be considered as the existence and the interaction with the players of the market resulted in non-adoption. With this example of a network industry, the results may also be of use for the introduction of other technologies in network industries.

Practitioners in technology marketing and sales from other industries can also benefit from the contribution to knowledge as part of this investigation. Focusing on technology-intensive industries, the quantitative research resulted in illustrated weighting schemes (Figure Q-1 to Figure Q-13) on the existence and importance of barriers considering different economic regions, types of products and high-tech industries. Applying the illustrated weighting schemes together with the main framework adapted from MacVaugh and Schiavone (2010), practitioners can benefit for decision-making of product, marketing and sales strategies in their context as the following graphic (Figure 6-1) illustrates.

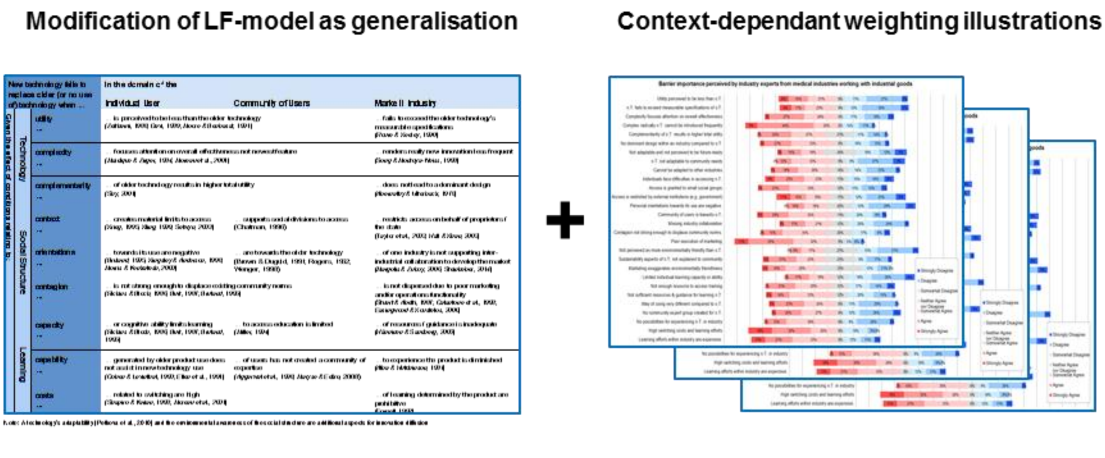


Figure 6-1 – LF-model & context-dependant weightings as practitioners' guideline

With the context-dependent weighting illustrations, a tailored use of the LF-model is possible. In the combined use, practitioners have the possibility of applying the generalised LF-model as framework in their specific context. Being less deterministic, this practical contribution to the diffusion of innovation research provides an interpretative applicability of its findings.

6.4 Limitations and further areas of research

6.4.1 Limitations of this research and its methodology

The presented results and conclusions do show limitations regarding the general research area and objectives but also regarding methodology. While limitations are presented in this section, another section gives recommendations for further research.

Nutley and colleagues explain, referring to Wolfe (1994), that in many publications about diffusion of innovation there exist some limits to its research and its methodology (Nutley et al., 2002). A portion of those also limit this research. Diffusion of innovation happens with many individual adoption decisions. Each can be described by various stages of the adoption decision process originating from Rogers (1995). This study does not specify at which stage the presented barriers occur or which are most important per the decision stage. While consideration is given to the industrial context, it is not researched how innovation characteristics and their perception changes over time, neither is the importance and relevance of the barriers over time researched.

The qualitative research shows some limitations. Using meta-matrices for analysis according to Miles and Huberman (1984), data from an unordered meta-matrix is reduced to less information by cluster analysis. Although the analysis was performed thoughtfully, it bears the risk that only a part of the data is looked at and is evaluated. Additional supporting techniques such as word frequency queries were not applied to analyse the interviews.

While the perception of the introduction of digital radio in Germany by industry experts was subject of the case study research, the listening population is not considered empirically. Empirical data gathering on the technology perception of listeners can provide a complementary view in addition to the results of the case study research. A similar limitation is the missing perception of customers as potential adopters, whose view is assumed to be represented by the target group of the survey. Due to the very specific focus of the case study research on a relatively small region, the broad results of the questionnaire may have limitations for confirming the case study research results. The industry subgroup to confirm the results consists of participants from all around the world and their perceptions. Moreover, the size of the subgroup was not very large. Others may therefore direct a similar questionnaire to stakeholders of the specific industry of digital radio and research its results on the existence of barriers.

The sampling and analysis approach have limitations for the quantitative research. With the applied non-parametric analysis less information is used and it is difficult to make quantitative statements about population differences in comparison to parametric analysis (Bluman, 2009). While the approach for sampling via a professional social online network is very powerful, some weaknesses are worth noting. Having focused on the professional social network of LinkedIn, it should be mentioned that the social media site used might correlate with regional area and language, race or socioeconomic, cultural or religious aspects of the practitioners as target group (Phillips, 2011). A sampling problem can also be the use of the researcher's own account to reach out for survey participants, as respondents are connected either directly or via a common group membership (Phillips, 2011). However, the mentioned groups were utilized to reach out for practitioners in related technology-intensive industries holding suitable job positions as form of community sampling besides self-selected sampling. With that sampling approach via the social network of LinkedIn, a potential sampling bias needs to be mentioned. Irrespective of a large number of participants, the social media users may not be entirely representative (section 3.4.4). It is assumed that most experienced persons are members of professional social networks especially in high-tech industries. However, this may not be the case for persons from emerging countries, where the popularity of social networks is different than in industrialized countries. Therefore, it can also be criticized that those respondents have a pro-innovation bias as they are using such social network services.

Reaching out via a professional network, the survey technique of the online questionnaire is used despite knowing its limitations in biases of recall and response;

and the length of the survey. The statements used to represent barriers of the LF-model and further potential barriers were researched empirically as diffusion challenges and then linked back to the model. While the LF-model structure consists of fragments of sentences, the statements were created as complete sentences, of which some have a slightly different wording. It should be highlighted that the research is based on the assumption that the according statements reflect the barriers of the LF-model. As the respondents were asked to evaluate these statements based on their experience, there is a risk of a potential misclassification of various types of barriers.

The resulting framework for practitioners is based on the integrated LF-model of MacVaugh and Schiavone (2010). Consequently, some limitations to the resulting model of this research are the same as for the LF-model. The authors of the LF-model do not have evidence that all barriers introduced actually caused non-use or non-adoption. In contrast to the case study research, this survey lacks as well of evidence, that the respondents' barrier evaluation and their importance is linked to a specific technology introduction that encountered challenges or even failed. The evaluation of barriers as part of this study is based on perceptions of experienced practitioners, but there is no proof for the barriers to have caused non-use or non-adoption.

An assumption for the LF-model is as well that a new technology is adopted to maximise utility. Because of this assumption, some aspects are not considered within this research. A good basis for further research on such barriers would be the investigations on psychological adoption barriers (Ram & Sheth, 1989; Hess; 2009).

Another limiting aspect of applying the LF-model is a shortcoming of interrelations of barriers. This is also outlined by MacVaugh and Schiavone (2010), stating that each important reason for non-adoption (referred to as barrier item within this research) may be related to others of the LF-model. The results of the case study research illustrate problem clusters which are mapped to several model variables and describe certain links between barriers as the reason for non-adoption of digital radio in Germany. Some relations are shown by qualitative research and the results of correlation tests are presented for the barrier variables used in the survey. However, the barrier items applied in the survey as statements were not tested on relations or correlations.

With the result of LF-model, its authors addressed practitioners. The investigation mainly focuses on the perceptions of practitioners in marketing, sales, business development and general management. As the differences between the perceptions of those organizational functions are not researched, the organizational angle of perspective of the research is very broad. Thus, the results of this research are not focused on one organizational function.

Although the LF-model is researched empirically, it originates from a theoretical and context-dependant model. For the utilization of the research findings in the form of the framework and supporting illustrations in practice, it needs to be pointed out that all weighting given to the existence and importance of barriers is based on the perception of practitioners in technology marketing and sales.

6.4.2 Further areas of research

Recommendations for further research areas can be given based on the limitations illustrated in the previous section, such as those related to the case study research. To add value to the case study research results, additional empirical research can be conducted on the millions of listeners as technology adopters. The results of the case study research and related papers (Steinheber, 2014) reflect the situation of Germany whilst in other countries the situation may be different. Others may research the introduction of digital radio in other countries and/or with other technologies.

The result of the quantitative research is mainly based on a questionnaire in order to present a generalised framework of barriers based on the LF-model. This research fills a gap of the model of MacVaugh and Schiavone with sufficiently strong evidence and triangulation via a mixed-methods approach. The research of other modifications with additional barrier aspects forming the variables of *environmental awareness* and technological *adaptability* provides a weaker triangulation, which is why only fragments are presented. Those can be a basis to perform theoretical or empirical research supporting them. Others may research the existence of these barriers regarding non-adoption of technology to contribute to this study and verify their validity. However, patterns and variations of according barriers are presented as part of this research.

As the research shows differences for economic regions, types of goods and different industries as findings, further research may be performed regarding the reasons for the described phenomena and correlations. Others may also research variances of diffusion barriers among different types of innovation, e.g. using the classification of Christensen (1997). While this study focuses on manufactured goods, other may research software. Similarities and differences to barriers for low and medium low-tech industries can also be researched. Further research can be performed, distinguishing between manufactured innovation and service innovation.

The integrated LF-model as basis for the resulting framework of this research consists of two dimensions. One dimension describes the extent to which a new technology meets different conditions for adoption (technology, social structure and learning) by model variables, referred to within this study. The other set consists of variables describing the extent to which the technology is useful in different domains. According to the recommendations of the LF-model authors, further research can be performed regarding interdependencies of main LF-model variables. Within this research such interdependencies are only briefly discussed referring to barrier variables from the LF-model and to the two additional barrier variable candidates (*environmental awareness* and *adaptability*) and their associations to the other main LF-model variables. Therefore, it is suggested that others research interdependencies of LF-model variables with LF-model domains. Furthermore, relations and interdependencies of the subordinate barrier items aspects themselves can also be subject of further research.

A framework for practitioners is presented, based on the LF-model. Additionally, illustrated weightings are given regarding specific industries. Expert interviews may be performed to verify them as identified industry-specific patterns. With expert interviews with practitioners of a specific industry following this research, the suggested framework concept can be discussed and questioned concerning its usability and the importance and existence of context-dependant barriers and potential facilitators to overcome them. As a possible direction for future investigation, this approach may also allow verifying the applicability of the framework and according weighting schemes.

Referring to generally known limitations of diffusion of innovation research (Nutley et al., 2002), potential changes over time can be subject for further research under very different aspects. During the time, diffusion is supposed to take place; perceptions of a technology and its benefits may change (Kim, 2009) and therefore, the importance or relevance of barriers might also change due to different reasons. Longitudinal research can focus on changed importance of barriers due to a changed strategy in sales and marketing as Moore (1991) describes referring to diffusion gaps. Longitudinal research can also be performed during the course of diffusion regarding changes in adopter characteristics along the technology adoption life cycle (Rogers, 1962; Moore, 1991) and changed importance and existence of diffusion barriers. A longitudinal approach may also be beneficial within a company in order to evaluate whether technology or marketing changes for a next generation result in avoiding certain barriers. Applying weighting schemes as described can support such a research strategy.

To conclude, more work has to be done on barriers for technology adoption and the diffusion of innovation. A lot of research on diffusion of innovation is focused on diffusion modelling and facilitators for adoption. However, more work on the topic of barriers for the diffusion of a new technology has to be undertaken to understand the existence, importance and interrelation of barriers and especially their relation to the context of the product’s, innovation’s and industry’s characteristics. Business practitioners could benefit from this and from further research regarding risk evaluation as underlying process of the development of business plans and the decision-making regarding new products with innovative technology.

6.5 Summary and implications to practice

In conclusion, this research presents contributions to the knowledge of diffusion of innovation research. A lot of new technologies fail on the market and diffusion of innovation does not take place. As this represents a high risk for companies, this study focused on problems of non-adoption of new technology. Specifically, a diversity of challenging barriers for the diffusion of innovation was researched and their context-dependency is illustrated by several variations.

As novelty, the barriers of the existing LF-model as a theoretical integrated model of factors limiting innovation adoption (MacVaugh & Schiavone. 2010) were researched empirically with a substantial database. Findings attained allowed its modification in order to fill an existing gap in the LF-model. Further contemporary diffusion barriers are presented as extensions of the model. With a focus on technology-intensive industries, this research provides a context-dependant idea of the importance and relevance of barriers for the diffusion of innovation.

As the research findings show, it is important for business practitioners to be aware of potential diffusion barriers, especially in technology-intensive industries. The framework and according weighting illustrations can be used as a guideline with the goal of diminishing market risks and thus preventing financial and reputational losses. The identification of barriers for a specific innovation preludes and facilitates decision-making for or against developing and launching a new technology.

This research had the objective of providing greater insight on occurring barriers with the introduction of technological innovations and giving aid to practitioners. In doing so, a particularly large database was used to empirically verify the theoretical LF-model. The large sample allowed this unique research of contemporary diffusion barriers. Results are presented both as a generalised pattern of importance of challenging barriers for the diffusion of innovation and as a context-dependent guideline for practitioners to reduce the risk of market failures with new innovations. This is especially important in the fast-paced, continuously changing world we live in.

“Failure is simply the opportunity to begin again, this time more intelligently.”

(Henry Ford, 1863-1947)

7. References

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Appendix A. Primary model of diffusion barriers

Given the effect of conditions relating to:	New technology fails to **replace older** (or no use of) technology when	In the domain of the: Individual User	Community of Users	Market / Industry
Technology	utility …	… is perceived to be less than the older technology *(Zeithaml, 1988; Davis, 1989; Moore & Benbasat, 1991)*		… fails to exceed the older technology's measurable specifications *(Roure & Keeley, 1990)*
	complexity …	… focuses attention on overall effectiveness not newest feature *(Maidique & Zirger, 1984; Moreau et al., 2001)*		… renders really new innovation less frequent *(Song & Montoya-Weiss, 1998)*
	complementarity …	… of older technology results in higher total utility *(Shy, 2001)*		… does not lead to a dominant design *(Abernathy & Utterback, 1978)*
Social Structure	context …	… creates material limits to access *(Krieg, 1995; Kling, 1999; Selwyn, 2003)*	… supports social divisions to access (Chatman, 1996)	… restricts access on behalf of proprietors / the state (*Taylor et al., 2003; Hall & Khan, 2003)*
	orientations …	… towards its use are negative *(Bruland, 1995; Kingsley & Anderson, 1998; Morris & Venkatesh, 2000)*	… are towards the older technology (Brown & Duguid, 1991; Rogers, 1962; Wenger, 1998)	-
	contagion …	… is not strong enough to displace existing community norms *(Richins & Bloch, 1986; Burt, 1987; Bruland, 1995)*		… is not dispersed due to poor marketing and/or operations functionality *(Stuart & Abetti, 1987; Calantone et al., 1993; Easingwood & Koustelos, 2000)*
Learning	capacity …	… or cognitive ability limits learning *(Richins & Bloch, 1986; Burt, 1987; Bruland, 1995)*	… to access education is limited *(Miller, 1994)*	… of resources / guidance is inadequate *(Hänninen & Sandberg, 2006)*
	capability …	… generated by older product use does not assist in new technology use *(Cohen & Levinthal, 1990; Ellen et al., 1991)*	… of users has not created a community of expertise *(Aggarwal et al., 1998; Maryse & Eelko,* 2008)	… to experience the product is diminished *(Alba & Hutchinson, 1987)*
	costs …	… related to switching are high *(Shapiro & Varian, 1998; Moreau et al., 2001)*		… of learning determined by the product are prohibitive *(Fornell, 1992)*

Note: The dark grey box indicates that, historically, a competitive market/industry has usually been oriented towards innovation diffusion

Source: From MacVaugh and Schiavone (2010) with modified appearance

Table A-1 – Original model of limiting factors to the diffusion of innovation

Appendix B. Overview of research methodology

Candidates for objectives			Tools	Dimensions
Research question	Objective candidates (research objective or personal objective)	Justification of objective from theory and literature	Method to address objective (e.g. interviews)	Target group (e.g. sample frame for interviews; survey etc.) or target model/method
Which are the barriers for diffusion of innovation during the current period?	- To identify barriers for innovations struggling or failing in its diffusion - To find a pattern of barriers (research objectives) - To become an expert for technical marketing (personal objective)	- Theoretical and empirical researches about barriers - Latest theoretical and empirical researches about barriers	- Case study approach - Survey approach for data collection (- Expert interviews within industry field)	- Marketing and product managers - Model of potential barriers to be overcome - Model of barriers for diffusion of innovation
Do changed environmental awareness and the need for adaptability imply the existence of different diffusion barriers compared to other diffusion of innovation research?	- To outline barriers related to environmental awareness and adaptability (research objective) - To know more about innovation trends of today, e.g. needs for adaptability and environmental friendliness (personal objective)	- Researches about current trends concerning co2 reduction and green technologies - Researches about a new generation and the need for change - Research of relevance to industry	- Case study approach - Survey approach for data collection (- Expert interviews within industry field)	- Experts for technology marketing - Model of diffusion of innovations
Do models or frameworks of barriers correlate? (e.g. chasm concept with other frameworks)	- To develop a framework integrating diffusion barriers (e.g. chasm-related barriers) and additional barriers - To pattern the inter-dependency of barriers (research objectives) - To apply it as a marketing method (personal objective)	- Theoretical researches about diffusion of innovation - Latest theoretical and empirical researches about barrier concepts and frameworks	- Case study approach - Survey approach for data collection (- Expert interviews within industry field)	- Industry experts - Model of potential barriers to be overcome - Model of barriers for diffusion of innovation
Are barriers, existing in one industry, comparable to barriers existing in other industries?	- To identify patterns of communalities and variations between high-tech industries. - To provide a guidance for decision-making with product, marketing and sales strategy to practitioners (research objective)	- Researches about barriers of different industries	- Survey approach for data collection	- Marketing and product managers - Model of diffusion of innovations - Model of potential barriers to be overcome

Table B-1 – Research questions, objectives and research methodology

Appendix C. Script for semi-structured interviews

Interview script for digital radio

1. Nature of the project (objectives, ethics protocol, transcript)

Objective:

This first section is of organizational nature: The interviewer explains the research project and the objective of the interview. An explanation of ethical constraints is given relating to the provided ethics protocol. The interviewer explains that data is recorded.

(Introducing the research)

- Possible introduction of the research:
  "I am researching various barriers for innovative technologies. The research study aims to investigate the perception of technological products under the circumstances of the 21st century. I will explore how technologies are perceived and why certain technologies do not find a successful way to the market. Thus the main objectives are to identify barriers for innovations to diffuse on the one hand and on the other hand to identify a pattern, how different barriers prevent innovations from diffusing. A third objective is to provide a guideline for practitioners. The model or framework shall be used as a guideline or suggestion in technology marketing in the 21st century."

- Possible introduction of the case study part:
  "As initial exploratory case study is planned to be performed with industry experts and their perception of the changes in the last decade. This initial case study is set in the sound broadcasting industry under the aspect of digitalization."

- Possible introduction of interviews:
  "Therefore I need to know what challenges industry experts, like you, see for the break-through of digital terrestrial sound broadcasting. I need to find out what reasons you see for either arguing the break-through or fall-down of the according technology. "

(Explanation of ethical concerns)

- Possible explanation:
  "If this sounds interesting for you, thank you very much for participating! According to ethics aspects of the University of Plymouth, I would like to point out, that you don't have to answer and you also have the possibility to withdraw from the study at any time."

(Explanation of ethical concerns)

- Handing out ethics protocol:
  "All ethical concerns, you'll find in this ethics protocol"

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Figure C-1 – Script for semi-structured interview on digital radio - page one

Interview script for digital radio

2. Introduction of Interviewee role and experience (position & responsibility)

Objective:

Clarifying the information richness and experience of the interviewee, he/she is asked to introduce him-/herself. The interviewer asks the interviewee to describe him-/herself and to sketch his/her job responsibility and company background

(Broadly asking)

- What is your name? Can you please sketch your job responsibility?

(Possible question to prompt)

- Are you a member of any subject network for an according standard?
- How old are you?
  17 or younger / 18-20 / 21-29 / 30-39 / 40-49 / 50-59 / 60 or older
- What is your job title?
- What is the highest educational degree you have received?

(Finalizing key questions)

- Can you tell me your current job title?
- How big is the company you are working for? No. of employees? Turnover?

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Figure C-2 – Script for semi-structured interview on digital radio - page two

Interview script for digital radio

3. Introduction of topic around "digital radio"

Objective:

Introduction of the topic explaining that in some countries as in Germany, new digital sound broadcasting standards have been set up. For questioning the success of the new standards of DAB and DAB+, the interviewee is asked to describe his/her understanding of „digital radio" and to describe which kind of listener would be interested in digital sound via the new standard.

(Explaining current situation)

- Possible description of worldwide digital radio situation:
  "In some countries as in Germany, new digital sound broadcasting standards have been set up. The success of these new standards ~~(HD Radio and DAB/DAB+)~~ is often questioned."

(Broadly asking)

- What do you understand under „Digital Radio" (Digital Sound Broadcasting)?

(Possible question to prompt)

- Are you a member of any subject network for an according standard?

(Finalizing key question)

- Which kind of listeners would be interested in digital sound?

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Figure C-3 – Script for semi-structured interview on digital radio - page three

4. Diffusion of digital sound broadcasting

Objective:

The interviewer asks about the diffusion of the technology receivers for digital sound broadcasting and their status concerning the replacement of FM Radios. The data necessary to collect are important factors for such a technology to be successfully introduced, which is asked for in the key question on the example of Germany.

(Broadly asking)

- What do you know about the status of Digital Radio receivers announced to replace FM Radios?

(Possible questions to prompt)

- Could you describe, where an introduction of a digital sound broadcasting standard has been successful. Why was it successful?
- In some countries no private radio stations are part of the new standards and the number of listeners is very limited. How big is the challenge for Digital sound broadcasting?
- Some national organization for media planning ~~(Landesmedienanstalt Thüringen)~~ mention, that it was important that listeners in public decide whether a technological development will make it or not. Can it be compared to the challenge of a marathon, where stakeholders need to be in a good athletic shape?

(Finalizing key question)

- What do you think are the most important factors for such a technology to be successfully introduced (e.g. in Germany)?

Figure C-4 – Script for semi-structured interview on digital radio - page four

Interview script for digital radio

5. Additional value of digital sound broadcasting

Objective:

The interviewer asks the interviewee about the perceived added value of digital sound broadcasting and how it is marketed compared to the old technology with the classical FM radio. Discussions may become very detailed focusing on technological differences. With the set of questions, the interviewee could be prompted to refocus.

(Broadly asking)

- What do you like about digital sound (broadcasting) compared to the classical UKW radio?

(Possible questions to prompt)

- Does Digitalization of Radio result in efficient spectrum utilization, if yes, at what price?
- How important is an Electronic Program Guide for Radio?
- In which way would there be High Fidelity Sound perception by listeners?
- Can you evaluate, whether a surround sound is required for the application of listening music on radio?
- Can you give priorities among the additional services of displaying short messages, stock news, soccer results and weather information? How would you judge its application as added value? Do you think that listeners would pay for those services, if they were encrypted?
- How green do you think is the approach of changing to Digital Sound Broadcasting?

(Finalizing key question)

- What is the most important additional value digital radios offer compared to the classical UKW radio?

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Figure C-5 – Script for semi-structured interview on digital radio - page five

6. Perception of digital sound broadcasting

Objective:

The sixth section is focusing on the personal perception of the interviewee concerning the marketing of the new radio technology in Germany. The interviewer asks the interviewee concerning marketing strategies perceived. The interviewee is also asked for a personal opinion in which way listeners may perceive the new technology of radio as green technology. The interviewer finally asks, what the interviewee would suggest to make better in promoting digital radio.

(Broadly asking)

- In which way have you perceived the way of marketing digital radio and the technology of digital Sound Broadcasting in Germany?
- How green do you think are listeners perceiving the new technology of radio?

(Possible questions to prompt)

- How frequently are you listening to internet radio?
- How do you think about the usage of social media or social internet platforms to market a new digital sound broadcasting standard?

(Finalizing key question)

- What would you suggest to make better in promoting digital radio, if you had the possibility of going back in time?

Figure C-6 – Script for semi-structured interview on digital radio - page six

7. Looking into the future of digital sound broadcasting

Objective:

The interviewer asks the interviewee to give his/her opinion about how the future looks like with radio as sound broadcasting. Potential future technologies as candidates competing or even substituting digital sound broadcasting might be mentioned. This section is already guiding to the key section of research about barriers for the diffusion of digital radio technologies in Europe but a focus needs to be on Germany.

(Broadly asking)

- How do you see the future of radio and sound broadcasting?

(Possible questions to prompt)

- How long will we be able to listen to the analogue audio signal of FM?
- Are FM, WLAN und Digital sound broadcasting standards, e.g. DAB+ co-existent? For how long? What is possibly the next step in the innovation of this technology?
- What do you think of internet and LTE technology as a future trend? Which additional options and which difficulties will there be?

(Possible information to prompt)

- Possible description of histories of digital sound broadcsting:
  "The digital standards have a long history. DAB und DAB+ have been discussed since the year 2000. HD Radio was introduced in 2005/2006. With the power of the internet and the LTE technology, new future-oriented possibilities are existing besides digital sound broadcasting."

(Finalizing key question)

- What do you think about future technologies already present endangering the diffusion of digital sound broadcasting?

Figure C-7 – Script for semi-structured interview on digital radio - page seven

8. (most critical) Barriers for the diffusion of a digital radio standard

Objective:

This section should discuss barriers preventing the digital radio technology DAB and DAB+ from its diffusion regarding difficulties influencing the transition path to the digital radio technology.
The existence of different standards with the new technology and hybrid solutions may be referred to (see prompting questions). Another prompting question is on governmental involvement as facilitator or as barrier, to which the interview can be prompted if necessary.
The interviewer asks for the main barriers for the diffusion of the digital radio standard in Germany. This section is the main focus of the research!

(Broadly asking)

- What about the difficulty in the transition path to the digital radio technology?

(Possible questions to prompt)

- What do you think of the availability of receivers? Are there a lot of receivers in the market?
- People might decide of additionally having other technology in their receivers prepared for IP-streaming. Are there sufficient multi-standard receivers in the market for an affordable price? **DAB vs. DAB+? In receivers?**
- Do you sense that there are organizations which strongly determine the success of market break-through? How important is governmental involvement? Have there been any governmental helps?
- What part has quality assessment and comparison to alternate technologies played in the diffusion of digital sound broadcasting technologies.

(Finalizing key question)

- What are the barriers for the diffusion of a digital sound broadcasting standard??
- What do you think are the most critical factors preventing the diffusion of a digital sound broadcasting standard?

Figure C-8 – Script for semi-structured interview on digital radio - page eight

Interview script for digital radio

9. Final remark, summary and explanation of data disclosure

Objective:

The interview is closed with a summary of section eight about barriers for the diffusion of digital radio. A final statement concerning the data disclosure needs to be made.

(Thanking for the interview participation)

- Possible line:
  "Thank you very much for the interview!!!"

(Explanation of data disclosure)

- Possible explanation:
  "I'll obviously be very careful not to write up any of this in a manner by which you can be identified. After the information is analyzed, you as participant of the interviews get the possibility to read through the transcription for potential withdrawing, according to the ethics guideline of University of Plymouth. The data will be destroyed in case the withdraw the data after the face-to-face interview."

(Questions regarding critical information)

- However, is there anything you've just told me which I should be particularly careful about?

- Anything I should check with you first before I use it?

(Closing the interview)

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Figure C-9 – Script for semi-structured interview on digital radio - page nine

Appendix D. Mindmap notes of semi-structured interviews

Figure D-1 – Mind map template for taking notes in semi-structured interviews

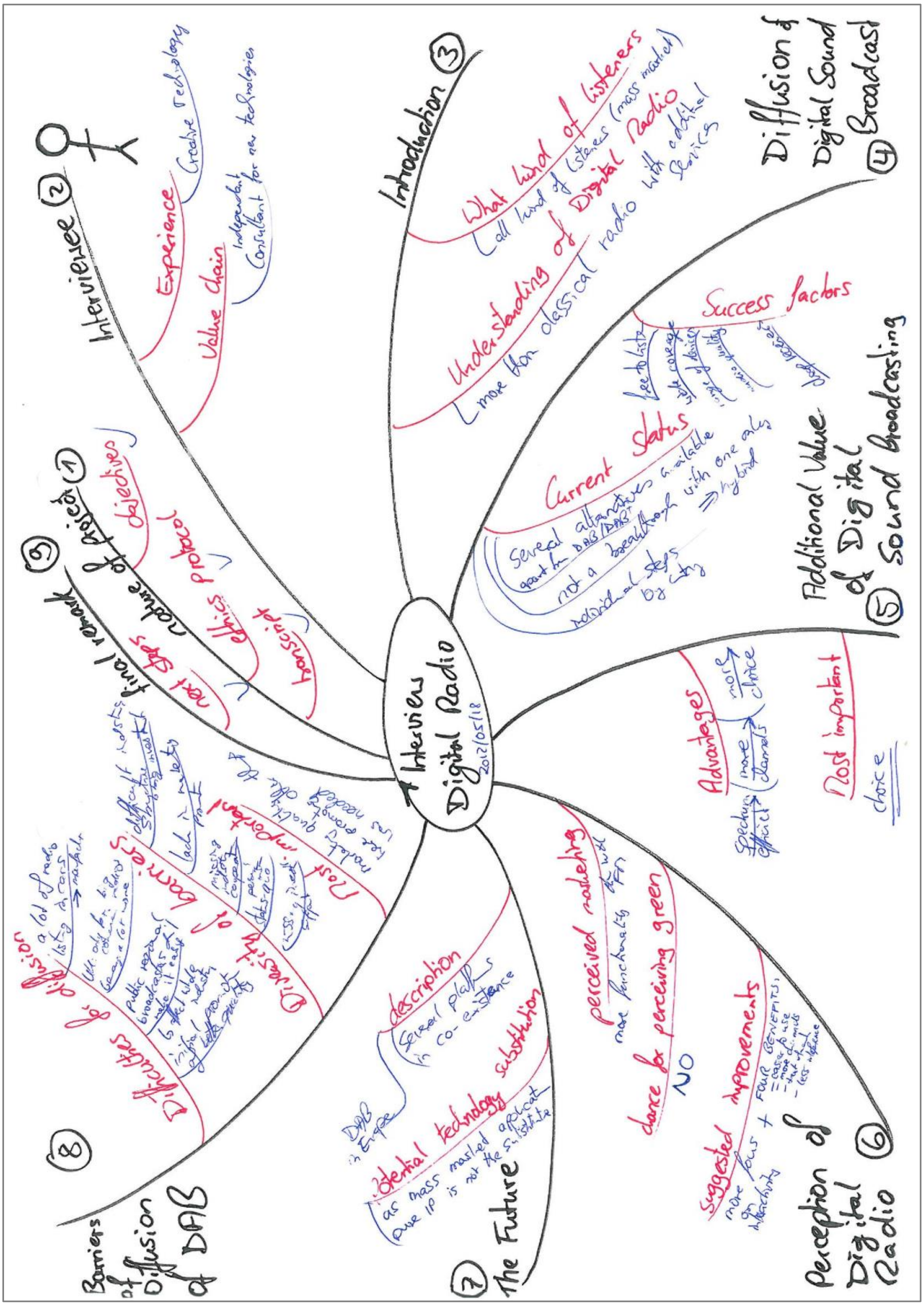

Figure D-2 – Mind map example 1 of notes taken in a semi-structured interview

Figure D-3 – Mind map example 2 of notes taken in a semi-structured interview

Appendix E. Questionnaire preparation and administration

Index Construct	Barrier variable as scale	Description of barrier variable construct as Likert scale
Technology Conditions	T_Utlty	The *utility* of the technology measured by two statements of different domains (T_Utlty_IC, T_Utlty_M)
	T_Cmplx	The *complexity* of the technology measured by two statements of different domains (T_Cmplx_IC, T_ Cmplx _M)
	T_Cmplm	The *complementarity* of the technology measured by two statements of different domains (T_Cmplm_IC, T_ Cmplm _M)
	T_Adptb	The *adaptability* of the technology as new barrier variable for the LF-model measured by three statements of different domains (T_Adptb_I, T_Adptb_C, T_Adptb _M)
Social Conditions	S_Cntxt	The *social context* within the social structure measured by three statements of different domains. (S_Cntxt_I, S_Cntxt_C, S_Cntxt_M)
	S_Orntn	*Orientations* within the social structure measured by three statements of different domains. For one statement an alternative is tested as well. (S_Cntgn_I, S_Cntgn_C1 or S_Cntgn_C2, **S_Cntgn_M**)
	S_Cntgn	*Contagion* as part of the social structure conditions measured by two statements of different domains (S_Cntgn_IC, S_Cntgn_M)
	S_EnvAw	The *environmental awareness* as part of the social structure as new barrier variable for the LF-model measured by three statements of different domains (S_EnvAw_I, S_EnvAw_C, S_EnvAw_M)
Learning Conditions	L_Cpcty	The *learning capacity* measured by three statements of different domains (L_Cpcty_I, L_Cpcty_C, L_Cpcty_M)
	L_Cpblt	The *learning capability* measured by three statements of different domains (L_Cpblt_I, L_Cpblt_C, L_Cpblt_M)
	L_CstLrn	The *cost of learning* measured by two statements of different domains (L_CstLrn_IC, L_CstLrn_M).

Barrier variable	Barrier item	Barrier statement
Utility (T_Utlty)	T_Utlty_IC	The utility (benefit) of the new technology is perceived to be less than the older technology.
	T_Utlty_M	The new technology fails to exceed the older technology's measurable specifications.
Complexity (T_Cmplx)	T_Cmplx_IC	The technological complexity makes it difficult to perceive new features. (The focus is rather on its overall effectiveness.)
	T_Cmplx_M	Radically new technology with a high level of complexity needs a lot of effort and therefore cannot be introduced frequently.
Complementarity (T_Cmplm)	T_Cmplm_IC	The complementarity of an older technology results in higher total utility. (e.g. existing standards and infrastructure)
	T_Cmplm_M	It does not lead to dominant design within an industry because an older technology retains a strong position in the market.
Adaptability (T_Adptb)	T_Adptb_I	It is not adaptable and is not perceived to be future-ready. Changes/upgrades are difficult.
	T_Adptb_C	The new technology cannot be adapted to specific needs (e.g. local needs) of a community.
	T_Adptb_M	It is for one specific application and cannot be adapted to be used in other markets or industries.
Social context (S_Cntxt)	S_Cntxt_I	Individuals face difficulties in accessing the new technology and related material (e.g. due to poor infrastructure).
	S_Cntxt_C	Corporate divisions or other communities restrict its access to only a few selected individuals (e.g. depending on their role, responsibility or their performance).
	S_Cntxt_M	Access is restricted by external institutions (e.g. government).
Orientations (S_Orntn)	S_Orntn_I	Personal orientations towards its use are negative.
	S_Orntn_C1	The community of users favours the older technology.
	S_Orntn_C2	There is already an even better technology (not available yet) under discussion within a community of users.
	S_Orntn_M	Industries, which are related to the new technology, are not cooperating to develop the market.
Contagion (S_Cntgn)	S_Cntgn_IC	The word-of-mouth or contagion effect is not strong enough to displace existing user community norms.
	S_Cntgn_M	Poor execution of marketing prevents positive word-of-mouth effect or contagion.
Environmental Awareness (S_EnvAw)	S_EnvAw_I	It is not perceived as being more environmentally friendly than the older technology.
	S_EnvAw_C	Sustainability aspects of the new technology are not published or are not explained to the community of users.
	S_EnvAw_M	Marketing is exaggerating when stating that it is environmentally friendly (e.g. by 'green' branding).
Learning capacity (L_Cpcty)	L_Cpcty_I	Individual learning capacity or ability to learn the new technology is limited.
	L_Cpcty_C	There is not enough resource in the organization or user community to access training.
	L_Cpcty_M	The technology producers are not providing sufficient resources and guidance for users to learn how to use it.
Learning capability (L_Cpblt)	L_Cpblt_I	The way of using it is very different compared to the older technology.
	L_Cpblt_C	No expert groups have been created for the new technology.
	L_Cpblt_M	Possibilities for experiencing or getting familiar with the new technology are limited within the industry.
Costs of learning (L_CstLrn)	L_CstLrn_IC	There are high switching costs and learning efforts for individuals and organizations with the new technology.
	L_CstLrn_M	The efforts needed for learning how to use the new technology within the industry are very expensive.

Table E-1 – Construction of barrier variables using barrier items

Investigative questions	Variables required	Detail in which data is measured	Type of closed question	Comment
What is the respondent's position / role?	Job area of respondent	Business Development / Engineering (R&D) / General Management / Key Account Management / Management Consultancy Marketing / Product Management / Project Management / Sales / Technology	category question	filtering possible for target group
Where is his/her location or residence?	country of residence	list of 193 countries	category question	according to UN (2013) list of countries / regrouped to geographic
	Age	less than 20; 10 year band; 20 - 70 range; more than 70	category question	Filtering possible regarding experience
	# years experience in	less than 1; 1-2; 3-4; 5-6; 7-8; 9-10; more than 10	category question	Filtering possible regarding experience
	revenue of product	< 1 Mio; 1-5 Mio; 5-10 Mio; 10-20 Mio; > 20 Mio	n/a	Confidential data! (Not used)
How representative are the responses of the managers?	Position	see job areas above	category question	
	Highest level of education	Less than High School / High School or Secondary School / 2-year College Diploma or Associate Degree / Bachelor Degree or equivalent / Master's Degree or equivalent / Doctorate(PhD)	category question	Evaluation of representativeness
Working with Innovative technologies?	Type of innovation	disruptive innovation; sustaining innovation (revolutionary); sustaining innovation (continuous);	Rating question (always-never) for each	Type of innovation is described in statements originating from Christensen (1997), which is rated on a scale of how frequently the respondent has to work with such a technology.
What type of good?	Industrial vs. consumer good	Industrial Good; Consumer Good	category question	
How long is their typical product life?	# years of Product life cycle	less than 1; 1-2; 3-4; 5-6; 7-8; 9-10; more than 10	category question	can be used for plausibility with type of good
What company size?	company size	less than 2; 2-10; 11-50; 51-250; 251-1000; 1,001-5,000; 5,001-10,000; 10,001-50,000; 50,00 -100,000; more than 100,000	category question	definition by European Commission for SME sizes
Which kind of industry?	Type of industry	Aeronautics, Defence & Space / Automotive / Chemicals / Computer Hardware/Networking / Computer Software / Consumer Electronics / Consumer Goods / Electrical/Electronic Manufacturing / Food & Beverages / Information Technology & Services / Logistics & Supply Chain / Machinery / Media Production/Distribution / Medical / Oil & Energy / Pharmaceuticals & Biotech / Renewables & Environment / Telecommunication / Other	list w/ "if other" than open question	Industries resulted from a mapping of (U.N. ISIC excerpt) & (LinkedIn industries) Filtering possible for medium high and high-technology industries according to Eurostat (2011)
What are the challenges for diffusion of technologies? (non-adoption)	existing barriers (partially originating from LF-model under the conditions of technology, social structure and learning)	evaluating all 11 barrier variables each with up to three different barrier items used as statements	Rating question: evaluating all 11 barrier variables each with up to three different barrier items used as statements	main focus of the research Statements represent barrier items, which are used to construct barrier variables

Table E-2 – Data requirements table of the survey

Variables required	Variable	Variable label	Detail in which data is measured	Codes for the data measured
Job area of respondent	JobPos	Job area	Business Development Engineering (R&D) General Management Key Account Management Management Consultancy Marketing Product Management Project Management Sales Technology Consultancy Other	1 = Business Development 2 = Engineering (R&D) 3 = General Management 4 = Key Account Management 5 = Management Consultancy 6 = Marketing 7 = Product Management 8 = Project Management 9 = Sales 10 = Technology Consultancy 11 = Other
country of origin	Country	Country of origin	list of 193 countries	different codes e.g.: 1 = Afghanistan ... 24 = Brazil 36 = China 65 = Germany 78 = India 79 = Indonesia 111 = Mexico 139 = Republic of Korea (South Korea) 142 = Russia 160 = South Africa 177 = Turkey 183 = UK 185 = United States … 193 = Zimbabwe
Age	Age	Age	less than 20; 10 year band; 20 - 70 range; more than 70	1 = less than 20; 2 = 20 - 29 years; 3 = 30 - 39 years; 4 = 40 - 49 years; 5 = 50 - 50 years; 6 = 60 - 69 years; 7 = 70 years or older
# years job experience	JobExp	Job Experience	less than 1; 1-2; 3-4; 5-6; 7-8; 9-10; more than 10	1 = less than 1 year 2 = 1 - 2 years 3 = 3 - 4 years 4 = 5 - 6 years; 5 = 7 - 8 years; 6 = 9 - 10 years; 7 = more than 10 years
Highest level of education	Edu	Highest level of education	Less than High School | High School / Secondary School | 2-year College Diploma / Associate Degree | Bachelor Degree or equivalent | Master's Degree or equivalent | Doctorate / PhD	1 = Less than High School 2 = High School / Secondary School 3 = 2-year College Diploma / Associate Degree 4 = Bachelor Degree or equivalent 5 = Master's Degree or equivalent 6 = Doctorate / PhD

…

Type of innovation	InnoDis		Statement for disruptive innovation	Scale from 1 to 5 1 = Always 2 = Most of the Time 3 = Sometimes 4 = Rarely 5 = Never
	InnoRev		Statement for sustaining innovation (revolutionary)	
	InnoEvo		Statement for sustaining innovation (evolutionary)	
Industr .Good	Good	Type of good	Industrial Good vs. Consumer Good	1 = Industrial Good; 2 = Consumer Good
# years of Product life	ProdLife	# years of Product life cycle	less than 1; 1-2; 3-4; 5-6; 7-8; 9-10; more than 10	1 = …; 2 = less than 1; 3 = 1-2; 4 = 3-4; 5 = 5-6; 6 = 7-8; 7 = 9-10; 8 = more than 10
company size	CompSize	company size	less than 2; 2-10; 11-50; 51-250; 251-1000; 1,001-5,000; 5,001-10,000; 10,001-50,000; 50,00 -100,000; more than 100,000	1 = less than 2 employees; 2 = 2 - 10 employees; 3 = 11 - 50 employees; 4 = 51 - 250 employees; 5 = 251 - 1000 employees; 6 = 1,001 - 5,000 employees; 7 = 5,001 - 10,000 employees; 8 = 10,001 - 50,000 employees; 9 = 50,000 - 100,000 employees; 10 = more than 100,000 employees
Type of industry and technology intensity	Ind	Type of industry	mapping table of (U.N. ISIC excerpt) & (LinkedIn industries)	1 = Aeronautics, Defence & Space 2 = Automotive 3 = Chemicals 4 = Computer Hardware/Networking 5 = Computer Software 6 = Consumer Electronics 7 = Consumer Goods 8 = Electrical/Electronic Manufacturing 9 = Food & Beverages 10 = Information Technology & Services 11 = Logistics & Supply Chain 12 = Machinery 13 = Media Production/Distribution 14 = Medical Devices 15 = Oil & Energy 16 = Pharmaceuticals 17 = Renewables & Environment 18 = Telecommunication 19 = Other
	Ind19			19?
	IndMan			*20 = Several industries *) manual
	IndRe			Re-categorization starting from 1
	IndHT			1 = High Technology 2 = Medium High-Tech 3 = Medium Low-Tech 4 = Low Technology
existing barriers for diffusion of	"X_Y_Z" with X: condition (T, S, L) Y: barrier Z: domain (I, C, M)	(Short form of statement)	(Complete statement as in questionnaire)	Scale from 1 to 7 1 = Strongly Agree 2 = Agree 3 = Somewhat Agree 4 = Neither Agree nor Disagree 5 = Somewhat Disagree 6 = Disagree 7 = Strongly Disagree

Table E-3 – Code book for variables applied in the online questionnaire

Coding instruction document

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0. Prelimary data (e.g. 1374 responses)

1. Recoding countries (acc. United Nations)

a. Recoding countries into geographical subregions (acc. United Nations)

b. Recoding countries into geographical regions (acc. United Nations)

c. Recoding countries&subregions into economic regions (developed, emerging & developing)

2. Recoding industries

a. Identification of additional industries mentioned when chosen „other industry“:

- 22 ‚Construction‘
- 23 ‚Mining, metals and minerals‘
- 24 ‚Maritime industries‘
- 25 ‚Textiles and clothing‘
- 34 ‚Healthcare industry'
- 35 ‚Biotechnology/Scientific Instruments'
- 36 ‚Wood, Paper & Printing‘

b. Evaluation of comment mentioned when chosen „other industry“:

- 20 'Several industries'
- 21 'no manufactured goods'

c. Recoding industries as merging industry type given:

- Medical Devices & Healthcare = Healthcare industry
- Pharmaceuticals + Biotech = Pharmaceuticals & Biotech

d. Recoding industries concerning their type of high-tech

- (manufactured technology acc. E.U publiciation)

3. Identification of Errors (e.g. 1280 responses after correction)

a. Answers incomplete (regarding the statements to be evaluated)

b. Age-20years > Experience in job

c. Product Lifecycle < 1year seems to be too low for manufactured goods

d. Frequency of working with innovation too low (rarely or never) for every type of innovation

4. Filtering according to research objectives (e.g. 920 responses after filtering)

a. Filtering

- Jobs in Marketing, Product Management, Business Development, General Management, Sales
- no micro enterprises
- only industries with manufactured goods (reduction to e.g. 920 responses)

5. Setting focus according to research objectives (e.g. 726 responses as group of focus)

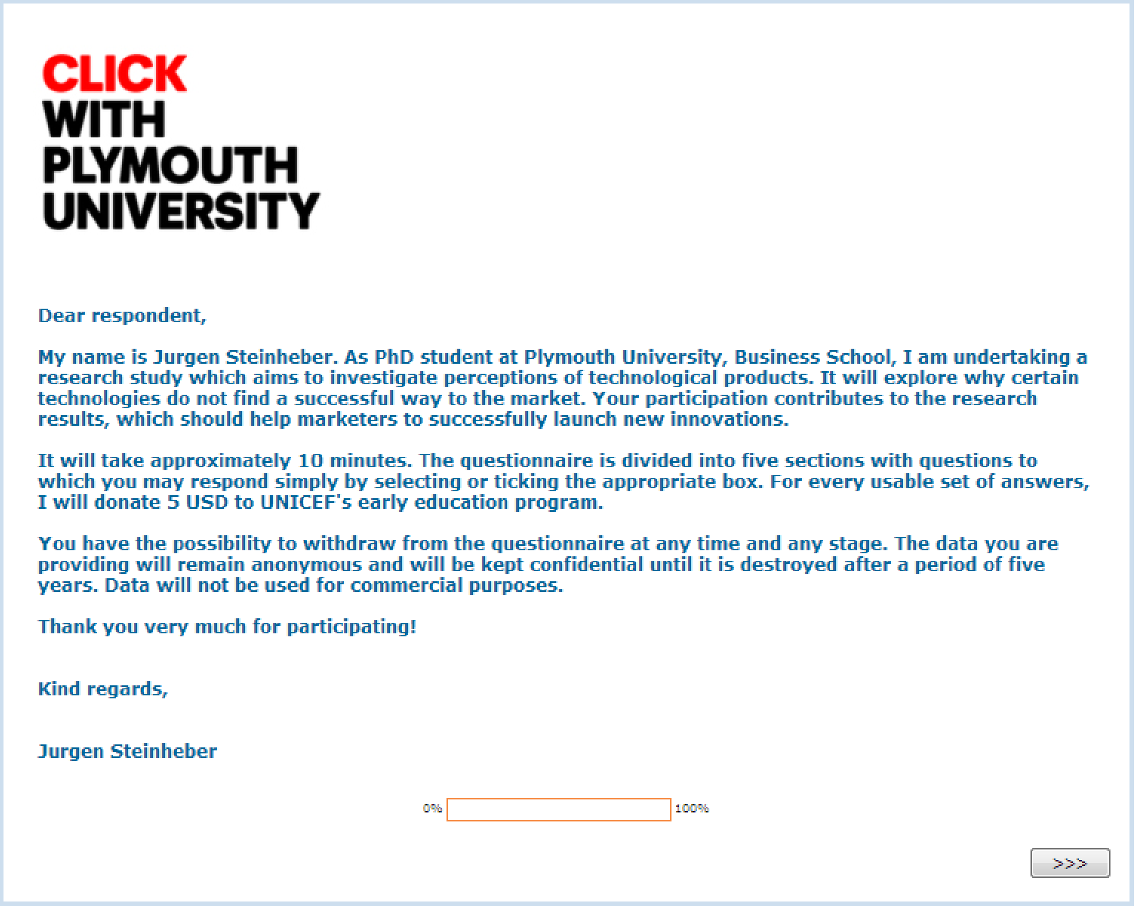
a. Setting focus

- with high-tech and medium high-tech industries only
- with developed and emerging countries only
- FOCUS of high-techn and medium high-tech and developed and emerging countries

Diffusion barriers of innovation

Figure E-1 – Coding instruction document

Appendix F. Appearance of online questionnaire



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Dear respondent,

My name is Jurgen Steinheber. As PhD student at Plymouth University, Business School, I am undertaking a research study which aims to investigate perceptions of technological products. It will explore why certain technologies do not find a successful way to the market. Your participation contributes to the research results, which should help marketers to successfully launch new innovations.

It will take approximately 10 minutes. The questionnaire is divided into five sections with questions to which you may respond simply by selecting or ticking the appropriate box. For every usable set of answers, I will donate 5 USD to UNICEF's early education program.

You have the possibility to withdraw from the questionnaire at any time and any stage. The data you are providing will remain anonymous and will be kept confidential until it is destroyed after a period of five years. Data will not be used for commercial purposes.

Thank you very much for participating!

Kind regards,

Jurgen Steinheber

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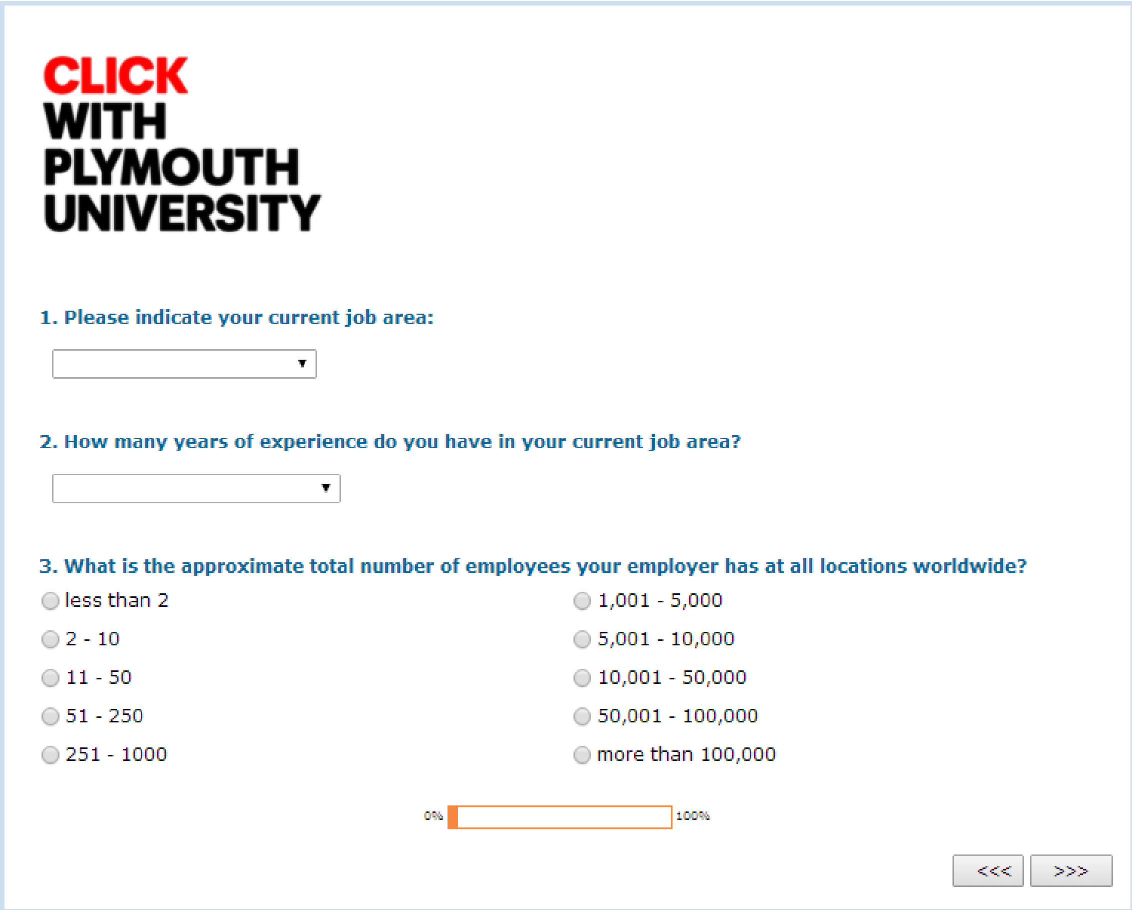
Source: Developed for the thesis based on Qualtrics (2012) software

Figure F-1 – Online questionnaire - cover page as introduction



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1. Please indicate your current job area:

2. How many years of experience do you have in your current job area?

3. What is the approximate total number of employees your employer has at all locations worldwide?

- less than 2
- 2 - 10
- 11 - 50
- 51 - 250
- 251 - 1000
- 1,001 - 5,000
- 5,001 - 10,000
- 10,001 - 50,000
- 50,001 - 100,000
- more than 100,000

0% 100%

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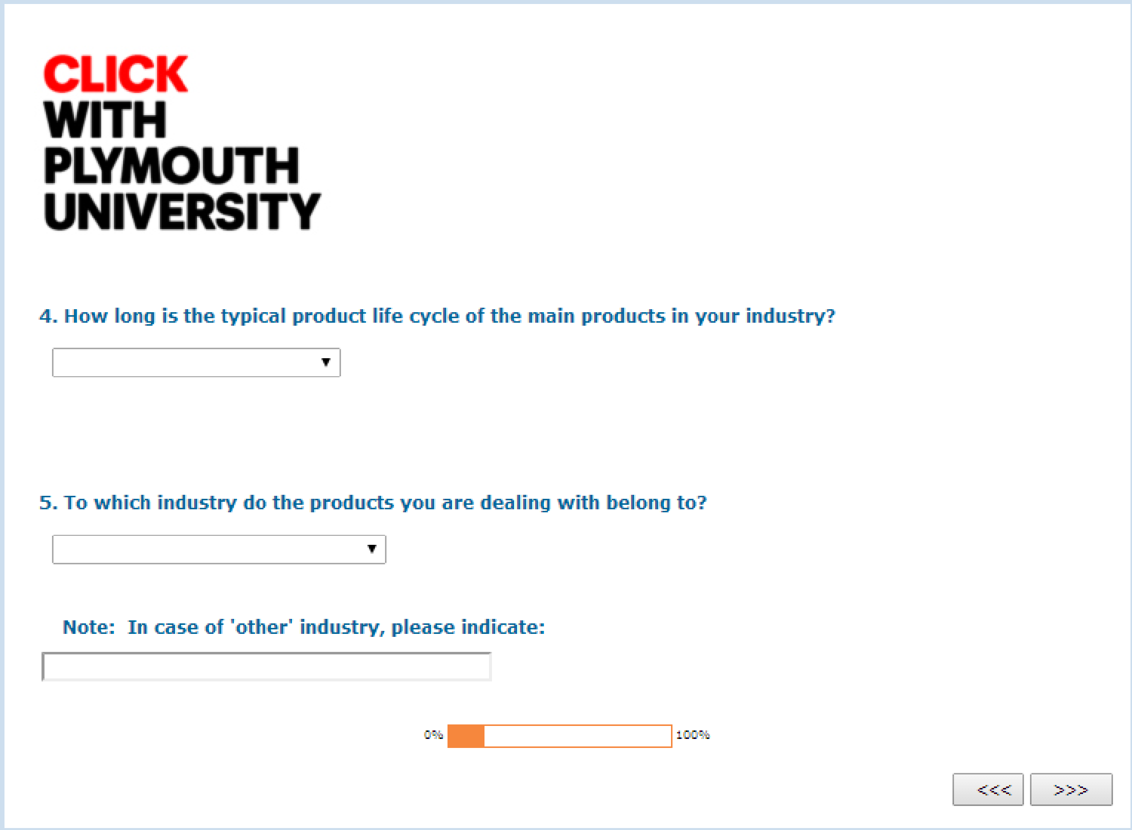
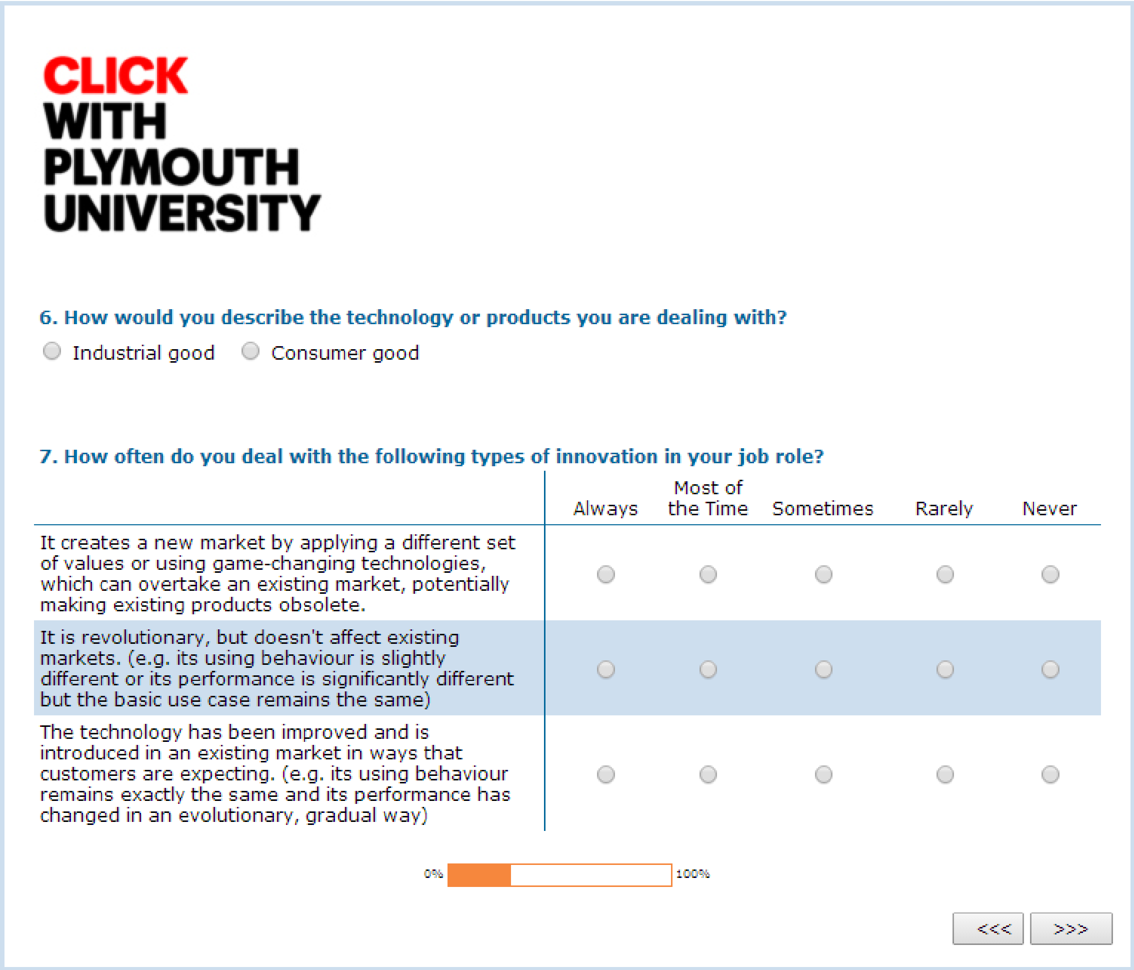
Source: Developed for the thesis based on Qualtrics (2012) software

Figure F-2 – Online questionnaire - page one with job-related data



Source: Developed for the thesis based on Qualtrics (2012) software

Figure F-3 – Online questionnaire - page two with industry-related data



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6. How would you describe the technology or products you are dealing with?

○ Industrial good ○ Consumer good

7. How often do you deal with the following types of innovation in your job role?

	Always	Most of the Time	Sometimes	Rarely	Never
It creates a new market by applying a different set of values or using game-changing technologies, which can overtake an existing market, potentially making existing products obsolete.	○	○	○	○	○
It is revolutionary, but doesn't affect existing markets. (e.g. its using behaviour is slightly different or its performance is significantly different but the basic use case remains the same)	○	○	○	○	○
The technology has been improved and is introduced in an existing market in ways that customers are expecting. (e.g. its using behaviour remains exactly the same and its performance has changed in an evolutionary, gradual way)	○	○	○	○	○

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Source: Developed for the thesis based on Qualtrics (2012) software

Figure F-4 – Online questionnaire - page three with technology-related data

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8. Although a technology is new, it might not be used or might not replace an older technology. To what extent do you agree that the situations described in the statements below represent significant challenges for a new technology based on your experience?

By ticking the appropriate box, please indicate your level of agreement with challenges for a new technology.

	Strongly Agree	Agree	Somewhat Agree	Neither Agree nor Disagree	Somewhat Disagree	Disagree	Strongly Disagree
The new technology fails to exceed the older technology's measurable specifications.	○	○	○	○	○	○	○
Radically new technology with a high level of complexity needs a lot of effort and therefore cannot be introduced frequently.	○	○	○	○	○	○	○
It does not lead to dominant design within an industry because an older technology retains a strong position in the market.	○	○	○	○	○	○	○
It is for one specific application and cannot be adapted to be used in other markets or industries.	○	○	○	○	○	○	○

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Please continue by ticking the appropriate box to indicate your level of agreement with challenges for a new technology based on your experience.

	Strongly Agree	Agree	Somewhat Agree	Neither Agree nor Disagree	Somewhat Disagree	Disagree	Strongly Disagree
Sustainability aspects of the new technology are not published or are not explained to the community of users.	○	○	○	○	○	○	○
The efforts needed for learning how to use the new technology within the industry are very expensive.	○	○	○	○	○	○	○
There is already an even better technology (not available yet) under discussion within a community of users.	○	○	○	○	○	○	○
Marketing is exaggerating when stating that it is environmentally friendly (e.g. by 'green' branding).	○	○	○	○	○	○	○
Corporate divisions or other communities restrict its access to only a few selected individuals (e.g. depending on their role, responsibility or their performance).	○	○	○	○	○	○	○

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Source: Developed for the thesis based on Qualtrics (2012) software

Figure F-5 – Online questionnaire - pages four/five with diffusion challenges

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Please continue by ticking the appropriate box to indicate your level of agreement with challenges for a new technology based on your experience.

	Strongly Agree	Agree	Somewhat Agree	Neither Agree nor Disagree	Somewhat Disagree	Disagree	Strongly Disagree
Industries, which are related to the new technology are not cooperating to develop the market.							
Poor execution of marketing prevents positive word-of-mouth effect or contagion.							
The technology producers are not providing sufficient resources and guidance for users to learn how to use it.							
Possibilities for experiencing or getting familiar with the new technology are limited within the industry.							
Access is restricted by external institutions (e.g. government).							

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CLICK WITH PLYMOUTH UNIVERSITY

Please continue by ticking the appropriate box to indicate your level of agreement with challenges for a new technology based on your experience.

	Strongly Agree	Agree	Somewhat Agree	Neither Agree nor Disagree	Somewhat Disagree	Disagree	Strongly Disagree
The community of users favours the older technology.							
The word-of-mouth or contagion effect is not strong enough to displace existing user community norms.							
There is not enough resource in the organization or user community to access training.							
No expert groups have been created for the new technology.							
There are high switching costs and learning efforts for individuals and organizations with the new technology.							

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Source: Developed for the thesis based on Qualtrics (2012) software

Figure F-6 – Online questionnaire - pages six/seven with diffusion challenges

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Please continue by ticking the appropriate box to indicate your level of agreement with challenges for a new technology based on your experience.

	Strongly Agree	Agree	Somewhat Agree	Neither Agree nor Disagree	Somewhat Disagree	Disagree	Strongly Disagree
The utility (benefit) of the new technology is perceived to be less than the older technology.	○	○	○	○	○	○	○
The technological complexity makes it difficult to perceive new features. (The focus is rather on its overall effectiveness.)	○	○	○	○	○	○	○
The complementarity of an older technology results in higher total utility. (e.g. existing standards and infrastructure)	○	○	○	○	○	○	○
It is not adaptable and is not perceived to be future-ready. Changes/upgrades are difficult.	○	○	○	○	○	○	○
Individuals face difficulties in accessing the new technology and related material (e.g. due to poor infrastructure).	○	○	○	○	○	○	○

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Please continue by ticking the appropriate box to indicate your level of agreement with challenges for a new technology based on your experience.

	Strongly Agree	Agree	Somewhat Agree	Neither Agree nor Disagree	Somewhat Disagree	Disagree	Strongly Disagree
The new technology cannot be adapted to specific needs (e.g. local needs) of a community.	○	○	○	○	○	○	○
Personal orientations towards its use are negative.	○	○	○	○	○	○	○
Individual learning capacity or ability to learn the new technology is limited.	○	○	○	○	○	○	○
The way of using it is very different compared to the older technology.	○	○	○	○	○	○	○
It is not perceived as being more environmentally friendly than the older technology.	○	○	○	○	○	○	○

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Source: Developed for the thesis based on Qualtrics (2012) software

Figure F-7 – Online questionnaire - pages eight/nine with diffusion challenges

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9. In which country do you reside?

10. What is your group of age?

younger than 20	20 - 29	30 - 39	40 - 49	50 - 59	60 - 69	70 or older
○	○	○	○	○	○	○

11. What is the highest level of education you have completed?

- ○ Less than High School /
- ○ High School / Secondary School
- ○ 2-year College Diploma / Associate Degree
- ○ Bachelor Degree or equivalent
- ○ Masters Degree or equivalent
- ○ Doctorate / PhD

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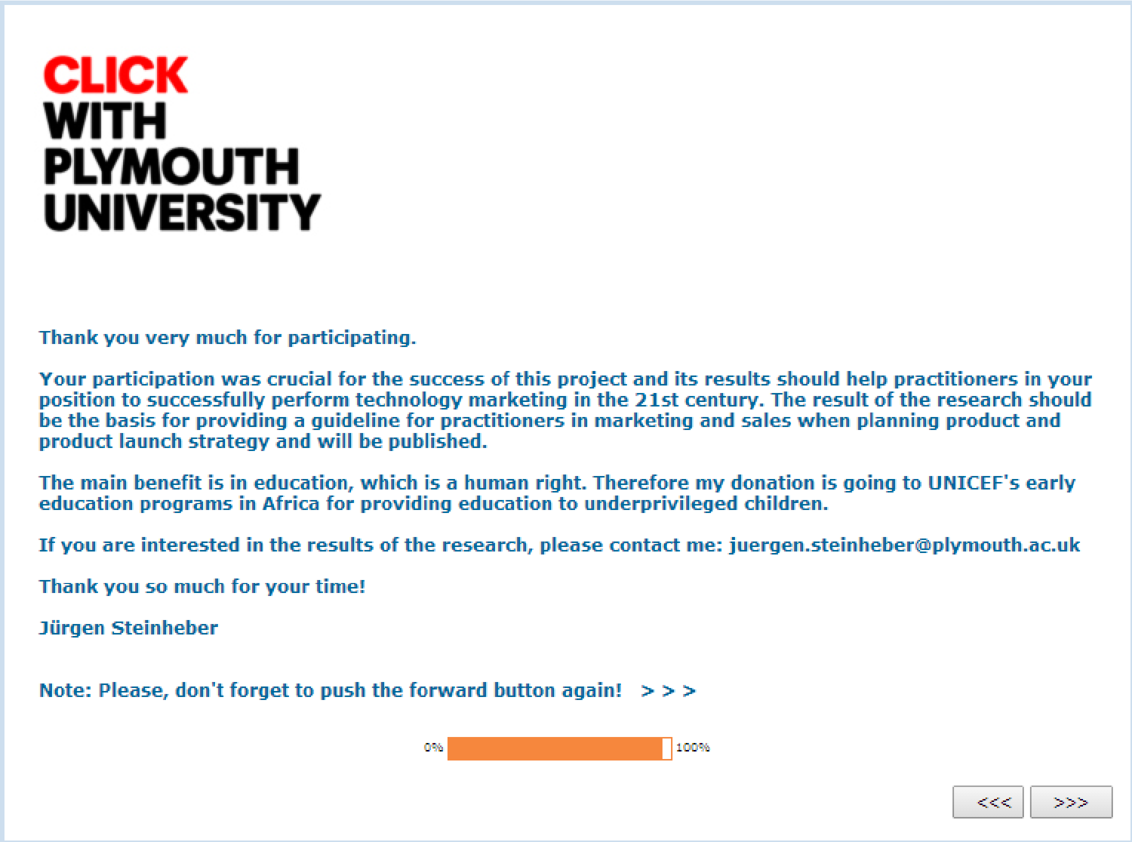
Source: Developed for the thesis based on Qualtrics (2012) software

Figure F-8 – Online questionnaire - page ten with person-related data



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Thank you very much for participating.

Your participation was crucial for the success of this project and its results should help practitioners in your position to successfully perform technology marketing in the 21st century. The result of the research should be the basis for providing a guideline for practitioners in marketing and sales when planning product and product launch strategy and will be published.

The main benefit is in education, which is a human right. Therefore my donation is going to UNICEF's early education programs in Africa for providing education to underprivileged children.

If you are interested in the results of the research, please contact me: juergen.steinheber@plymouth.ac.uk

Thank you so much for your time!

Jürgen Steinheber

Note: Please, don't forget to push the forward button again! > > >

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Source: Developed for the thesis based on Qualtrics (2012) software

Figure F-9 – Online questionnaire - final page for closing and saving data

Appendix G. Attempt of exploratory factor analysis

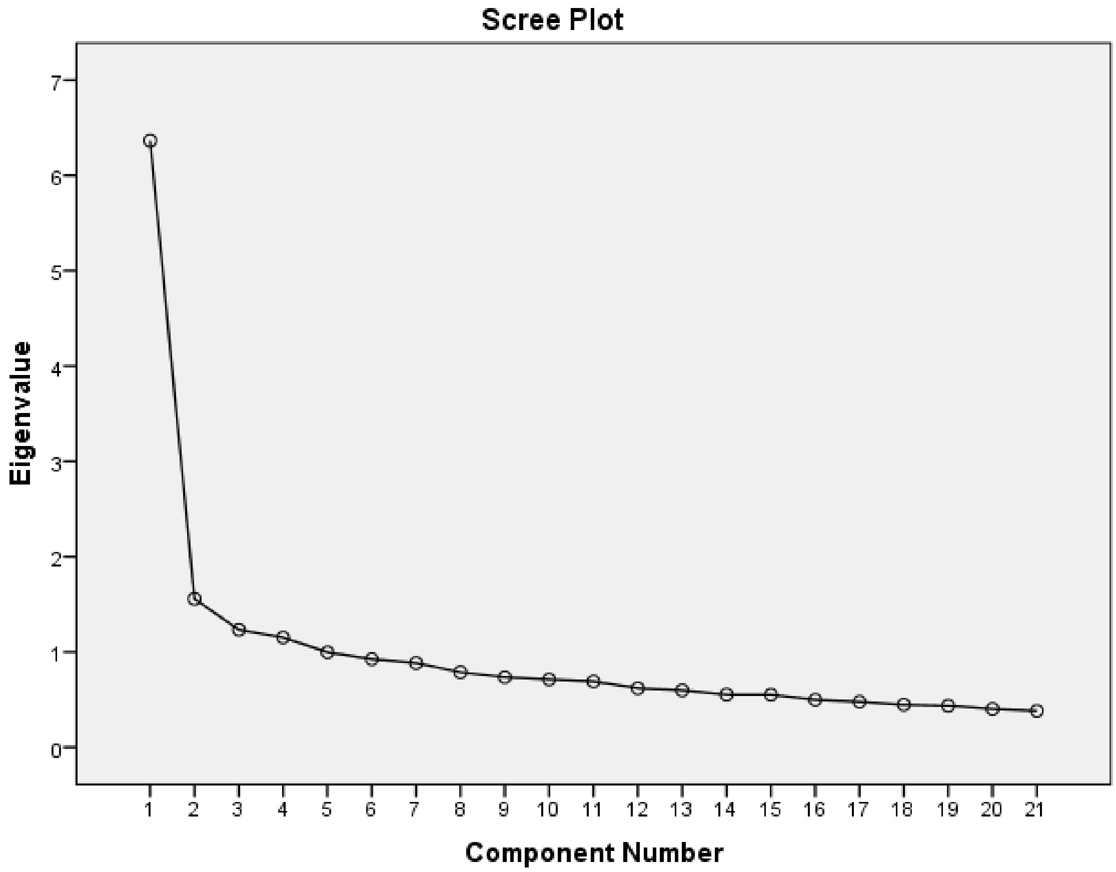

Figure G-1 – Scree plot diagram to extract number of components

Component Matrix[a]

	Component			
	1	2	3	4
Utility perceived to be less than o.T.	,615			
n.T. fails to exceed measurable specifications of o.T.	,470	,385		
Complexity focuses attention on overall effectiveness	,652			
Complex radically n.T. cannot be introduced frequently	,391	,542		
Complementarity of o.T. results in higher total utility	,543			
No dominant design within an industry compared to o.T.	,488	,537		
Individuals face difficulties in accessing n.T.	,664			
Access is granted to small social groups	,358	-,391		,467
Access is restricted by external institutions (e.g. government)	,465	-,327		
Personal orientations towards its use are negative.	,591		-,380	-,329
Community of users is towards o.T.	,572			-,385
Contagion not strong enough to displace community norms.	,556		,341	-,376
Poor execution of marketing	,432			
Limited individual learning capacity or ability	,606		-,431	
Not enough resource to access training	,623		,305	
Not sufficient resources & guidance for learning n.T.	,630	-,310		
Way of using very different compared to o.T.	,466		-,429	
No community expert group created for n.T.	,567		,313	
No possibilities for experiencing n.T. in industry	,599	-,310		
High switching costs and learning efforts	,594			
Learning efforts within industry are expensive.	,543			,329

Extraction Method: Principal Component Analysis.

a. 4 components extracted.

Table G-1 – Principal component analysis (w/o oblim rotation)

Structure Matrix

	Component			
	1	2	3	4
Utility perceived to be less than o.T.			-,576	
n.T. fails to exceed measurable specifications of o.T.		,590		
Complexity focuses attention on overall effectiveness		,585	-,566	
Complex radically n.T. cannot be introduced frequently		,724		
Complementarity of o.T. results in higher total utility		,555		
No dominant design within an industry compared to o.T.		,712		
Individuals face difficulties in accessing n.T.	,514		-,654	
Access is granted to small social groups	,706			
Access is restricted by external institutions (e.g. government)	,593			
Personal orientations towards its use are negative.			-,749	
Community of users is towards o.T.				-,688
Contagion not strong enough to displace community norms.				-,750
Poor execution of marketing	,589			
Limited individual learning capacity or ability			-,773	
Not enough resource to access training				-,673
Not sufficient resources & guidance for learning n.T.	,606			-,520
Way of using very different compared to o.T.			-,652	
No community expert group created for n.T.				-,659
No possibilities for experiencing n.T. in industry	,590			
High switching costs and learning efforts		,556		
Learning efforts within industry are expensive.		,551		

Extraction Method: Principal Component Analysis.
Rotation Method: Oblimin with Kaiser Normalization.

Table G-2 – Principal component analysis with four components set (w/ oblim)

Structure Matrix

	Component		
	1	2	3
Utility perceived to be less than o.T.	,609		
n.T. fails to exceed measurable specifications of o.T.		,572	
Complexity focuses attention on overall effectiveness	,643		
Complex radically n.T. cannot be introduced frequently		,681	
Complementarity of o.T. results in higher total utility	,513		
No dominant design within an industry compared to o.T.		,770	
Individuals face difficulties in accessing n.T.	,681		,535
Access is granted to small social groups			,531
Access is restricted by external institutions (e.g. government)			,545
Personal orientations towards its use are negative.	,702		
Community of users is towards o.T.		,581	
Contagion not strong enough to displace community norms.		,534	,518
Poor execution of marketing			,556
Limited individual learning capacity or ability	,749		
Not enough resource to access training			,703
Not sufficient resources & guidance for learning n.T.			,719
Way of using very different compared to o.T.	,632		
No community expert group created for n.T.			,645
No possibilities for experiencing n.T. in industry			,683
High switching costs and learning efforts		,509	
Learning efforts within industry are expensive.			

Extraction Method: Principal Component Analysis.
Rotation Method: Oblimin with Kaiser Normalization.

Table G-3 – Principal component analysis with three components set (w/ oblim)

Structure Matrix

	Component								
	1	2	3	4	5	6	7	8	9
Utility perceived to be less than o.T.					-,694				
n.T. fails to exceed measurable specifications of o.T.							,814		
Complexity focuses attention on overall effectiveness					-,768				
Complex radically n.T. cannot be introduced frequently		,841							
Complementarity of o.T. results in higher total utility					-,811				
No dominant design within an industry compared to o.T.		,685							
Individuals face difficulties in accessing n.T.	,513		-,553		-,524				
Access is granted to small social groups						,824			
Access is restricted by external institutions (e.g. government)						,766			
Personal orientations towards its use are negative.			-,751						
Community of users is towards o.T.				-,812					
Contagion not strong enough to displace community norms.				-,816					
Poor execution of marketing								,910	
Limited individual learning capacity or ability			-,805						
Not enough resource to access training	,819								
Not sufficient resources & guidance for learning n.T.	,654								
Way of using very different compared to o.T.			-,755						
No community expert group created for n.T.	,818								
No possibilities for experiencing n.T. in industry	,504								-,535
High switching costs and learning efforts					-,516				
Learning efforts within industry are expensive.									-,761

Extraction Method: Principal Component Analysis.
Rotation Method: Oblimin with Kaiser Normalization.

Table G-4 – Principal component analysis with nine components set (w/ oblim)

Appendix H. Ethics protocol

CROSSING THE CHASM IN THE 21ST CENTURY

Juergen Steinheber

ETHICS PROTOCOL

THE PROJECT

With an initial case study and a survey the project consists of 2 basic elements. Potentially there are further optional expert interviews following the survey.
The studies aim to investigate the perception of technological products under the circumstances of the 21st century. They will explore how technologies are perceived and why certain technologies do not find a successful way to the market.
An initial exploratory case study is supported by in-depth interviews with industry experts and their perception of the changes in the last decade. Qualitative data therefore will be obtained from personal interviews at agreed meetings. These could be industry gurus, technology manufacturer, manufacturers of complementary technology, members of official authorities and committees or potential customers. This initial case study is set in the sound broadcasting industry under the aspect of digitalization.
The survey for generalization will be set up to identify barriers when launching innovative technological products. The survey shall be the basis for identifying a pattern of certain factors being important in the 21st century. Within the survey various types of data are asked for. The quantitative data gathering via a questionnaire is agreed with according supervisors.
Potentially, optional interviews will research the outcome of the survey and help to built a framework for practitioners. The model or framework shall be used as a guideline or suggestions in technology marketing in the 21st century.

What it will entail

- Interviews with key stakeholders of other industrial environments
- Questionnaire to product marketing managers of various industrial fields

Informed Consent

Participants (which are stake holder of technologies, industry gurus, technology manufacturer and potential users) of interviews or participants (product manager, marketing managers) of surveys will be given a copy of the ethics protocol and any questions about the study will be answered. Where people are concerned, permission will be coordinated with the PhD supervisor.

Right to Withdraw

All participants will be offered the option not to answer questions or to withdraw from the study at any time.

Feedback

A summary of the research findings will be available for all participants at the conclusion of the study by contacting a member of the research team, and copies given to the interviewed organization for distribution.

Anonymity and Confidentiality

Transcripts of interviews, completed questionnaires and all other collected data will be kept confidential and only used for research purposes. Published data will be generic rather than specific. Names of interviewees will not be included. Whenever it is impossible to guarantee the organization's or interviewees' anonymity, the name of the organization will only be used in publications with the head of organization's consent. Drafts of written papers and articles will be checked with the head of organization for factual accuracy prior to publication. Responsibility for the interpretation of data remains with the research team.

Thank you very much for taking part in this research.

If you wish to discuss this study, please contact:
Jürgen Steinheber Tel: +49 (0) 174 2572524 Email juergen.steinheber@plymouth.ac.uk

Appendix I. Matrices for case study analysis

Area of value chain		Interviewee short	Interviewee description
Interviewees along the value chain of digital radio	Studio & Radio Stations	**ModeratorDAB**	Moderator of a DAB radio station
		ExModMarketer	Ex radio moderator and marketer
		EdModContent	Editing manager for content and ex moderator
		AdvSalesMana	Advertisement and sales manager
		EdMediaMana	Editor and media manager
	Broadcasting Infrastructure	**ContentPlay**	Content and playout systems
		IT infrastructure	Radio IT infrastructure
		TransManu	Transmitter manufacturer
		NetProv	Network provider
	Receiver Manufacturers	**ChipManu**	Chip manufacturer
		CarManu	Car manufacturer
		RecManu	Receiver manufacturer
Industry consultants	Radio & Broadcasting Expert Group	**StandForum**	Standardisation Forum member
		RadioFutur	Radio futurologist
		RadioConsu	Radio consultant
		InfraServiceAUS	Infrastructure service engineer Australia

Table I-1 – Structure of the unordered meta-matrix: Aspects of digital radio

			3		4		5			6		7		8		
			Understanding of "Digital Radio"	Kind of Listeners	Current Status	Success Factors	Advantage of Digital Radio	Important added value	perceived marketing so far	Chance for perceiving as greener	suggested improvement for marketing technology	Future of Radio is . . .	future technology substitution of DAB	Difficulties for the Diffusion	Diversity of barriers for the Diffusion	Most important barrier
Area		Interviewee														
		ModeratorDAB	People think it might be online: "I don't think there's anyone who is not particularly working for broadcasting who actually has any idea about digital broadcast, because they all think it might be online. "	/ Possibly the cliché of the 60year old, classical music admirer who would love the proper sound. / Young people interested in more choice.	/ With digital TV poeple think the digitalization might happen to radio, too. "But it hasn't!" "Everyone keeps their old radio, the old machine, so they don't swap!" / status: "…nothing is happening acutally, or nothing has happened." / DAB only stations realize, that without FM frequency, they would not have success. (digital broadcasting is not going to work.)	/ enthusiasm for a new technology (difficult) / people have to be forced to it	/ used to be better sound, more choice, extra information with the original idea / right now: none	no perceivable added value now	/ There hasn't been any marketing: "I can't remember one big marketing campaign!" / Individual approaches of broadcasters without big impact	/ not obviously green / has never been an argument	/ special programmes for DAB / switching-off FM / no simulcast	… used by people less and less. More podcasts. Radio via internet is more demanded.	Internet technologies: "…for normal users it might seem interesting to use the internet without DAB"	/ perception that receivers are only among people working in the broadcasting industry / years ago it was a new technology, now this dynamics is low / advantages of the technologies got lost in the years: "… can't see any advantages for having a new digital broadcast device!!" / unsuccessful marketing / simulcasting at the beginning did not create added value with an additional program: "…at least in the very beginning there was never any such a program."	/ missing benefit: "… it hasn't achieved in showing people that it's something better than normal FM radio." / diffusion too long (added values not available any more) / marketing without any impact / good old technology: "We need the old technology, if we don't get the old technology the whole radio will fail." / not better than FM / old technology: "on the one hand it's modern, on the other hand it seems very old fashioned." / contagion - people don't know about it / no need for an expensive transmitter / lack of governmental support in shut-down FM	missing marketing is reason that only few people know about it: "It wasn't like a big bang or (…) something really big has happened in radio technology"
		ExModMarketer	Listening to radio with a "better broadcasting performance and you have the possibility to bring more information and data next to the customer."	completely new group of listeners but in Germany mainly car drivers	The DAB project: has been developed into a wrong direction: "it's about 20 years ago. So I think it's now a really big gap between the wishes of the industries and all these people and between the reality. / 20 years without progress: "I was really in the mindset that it's a brilliant technology and we get DAB in the next month (…) But 20 years later we see that we have nearly no DAB"	/ Simplicity as an iPhone: "The phenomen of the iPhone is you have a smart and easy access to the new technology and the people want to use the technology." /	/ Sound Quality / Nation wide reception (no need for tuning)	better quality	/ some press work from Bayerische Landesanstalt für Neue Medien. / without the internet there was "no information where you can buy a receiver like that."	not perceived at all	improve branding and cross the gap of a lack of information: put more effort into explaining how the technology works: "you have to make a spirit, an idea of the technology and what's the benefit (…)"	… depending on the location. In urban areas, Internet technologies will dominate. In rural areas, there might be the possibility to still have terrestrial broadcasting. / Accessability from all over in future: "People want to take their music all their life with them. So if they have the possibility to have the favourite radio station all over the country all over Europe, (…) i's a great thing."	Webstreaming brings a lot of benefits: "…brilliant chance ot get my favourite radio station (…) from California, from I don't know. I can bring the feeling, the spirit of the sound from my holidays, yes, I can bring it to my office."	/ One problem lies in the receiver business: "We've no really good products in the field of digital audio broadcasting." / Too expensive: "I have not the chance for some more money to get the DAB in my car" / Not in the focus of technology enthusiasts: "It's early adopters which are using new technologies and bring these to the mass of the market. (…) just one look to Google, then you will see, it's a 20 years old technology (…) it's the wrong product for people who love trends and to be a techie." / Only regional initiatives at the beginning: "it was just the state of Bavaria who made some efforts to push this DAB project." / no industry pushes: "there was no effort from industry at this time" of introduction / lack of information and problem of branding: "…the most people I think, if you are listeningto DAB, the most people think it's web radio." / It has to be explained what the benefit of it is.	/ benefit is not that obvious / no marketing / old technology compared to what is available with ipods and smartphones	contagion / alternatives
		EdModContent	brand name for DAB - Digital Audio Broadcasting	/ nerds who are interested in the technology / those who need to have a trial for their job	/ 90s: ready for transition with plan for FM-switch-off / 2012: no diffusion, plan for switch-off is postponed (not much hope) / nevertheless, regional broadcasters stick to the technology, since they fear webradio (power need)	/ political regulation to e.g. have for a period in time only hybrid (FM, DAB) receivers in automobiles / there should be an explainable reason to change for a normal listener	/ for broadcasters: theoretically lower energy consumption, once FM is switched off / selling argument: technology with better quality / more choice	no added values perceived, only bought because of technology curiosity (except football radio)	small effort of communicating higher quality and more choice		/ difficult, since there are no arguments ot market it successfully / as retrospective, the idea should have been thought through	… is FM as main distribution technology within the next 15 years. More internet usage support additional sound and data distribution	/ IP streams are already present right now in our smartphones. There would not be the need for DAB, since millions of people are using their smartphone. / webradio can bring homeland feeling all over the world in times where people are more mobile than ever	/ price for receivers (FM: 3€ vs. DAB: >80€) / no big market for special content / quality was bad at the beginning and as consequence people listened CD or FM (in contrast to marketing slogans) / with the first DAB programs, there was not more choice (in contrast to marketing slogans) ==> no proofing, convincing and explaining added value / there was no demand at all for a better quality among people / conceptual error having a technology focus but not a focus on end user needs / DAB receivers buyer got dispeased when DAB+ was introduced / biggest marketing error: First DAB stations were offered FM frequencies to have the possibility of promoting the technology via FM ==> added value of different content got destroyed (very absurd: to market one medium with content via another medium with the same content!!)	/ price / behavioral change needed / no benefit/added value (neither for listener nor for industry e.g. car manufacturer) / FM technology already satisfies needs of people / lack in marketing (big errors) / quality worse compared to FM / diverse interests of stakeholders (difficulties in industrial cooperation)	/ technology push not focused on end user at all / marketing error, which eliminated added value of different content
		AdvSalesMana	there are two types of digital radio, of which one until lately was an automated 24/7 playlist. The other ist streaming.	In general supposingly the same kind of listeners but no ones uses it	STATUS QUO since 12 years: / not much receivers used, only by technical freaks (innovators) are using it / no coverage in the country side / radio stations have a small obligation to promote, but get no (positive) feedback at all / change from DAB to DAB+ not a problem, since nobody used it anyway: "There are so little users; I don't think that it was a big step into the development of the new technology and the development of DAB. I don't think so. I realise that it is a better quality now in DAB+ because I have a DAB receiver all the time and I now have a DAB+ receiver, but if you look at the selling for the receivers, they are really, really low. They don't sell much of this technology, these receivers, I don't think people even realise there was a switch."	/ low cost receivers / get it started soon / governmental pressure (e.g. with subventions) that forcess all (broadcasters, industries, retailers,…): "why should they otherwise?" / integrating it into iPhones	/ additional future advertisements / basic idea of quality	if there is reception: quality	no awareness has been generated: even within the radio station people are asking "what is DAB and what are the benefits?"	probably not	marketing for massed (early majority) not for technology freaks (innovators)	… the internet, since the number of channels is growing and a lot more people are using it.(it is also a perfectly customizable target group) … not DAB or DAB+ since it has grown old before it was attractive	internet streams, since information which is provided by additional services in DAB can be accessed via internet as well	"Why switch to that technology" as leading question for both listeners and industrial stakeholders: / supposed to have better quality but the perception of listeners was not like that (especially in the countryside), since they couldn't hear the difference in quality / no awareness has been generated / for radio stations there have not been possibilities to earn money in 12 years / Since radio stations needed to have content to get licences thinking "maybe it is the future", they initially did use computers for a 24/7 playlist (now its only simulcast) / no one uses additional features due to internet as substitute / receivers are too expensive (automotive did not put receivers as standard and not all cars have it)	/ no benefits can be perceived (quality, services, choice) / missing contagion / substitute technology available / receiver costs are too high (40-80€) / no governmental pressure / limit in availability (cars) / technology substitute availabe with smartphones	internet as competing technology for the services being exactly those aspects which were the benefits some years ago
	Studio & Radio Stations	EdMediaMana	other format of terrestrial radio transmission	all kind of listeners are targeted, since it is a mass media	The view from 1999 was that it would be the "future of radio", but nothing happened	/ suitable for mass media / receivers which automatically have both (Hybrid) for a smooth replacement	/ not tuning needed / added values, such as logo, added service, text, logo (difficult to perceive) - comparable with FM's RDS information	no tuning	no marketing just a little bit of lobby communication	not at all	it's not only a marketing problem. The basic question to be solved is how to replace a perfectly working global standard	… is not DAB/DAB+. There will always be radio, probably FM, but it remains a passive media. Internet can be used additionally.	Mobile internet is changing the behaviour towards media, e.g. related to additional services. New technologies (webstreams via LTE) are endangering DAB services but not FM.	Rather a conceptional problem: / People listen to radio in a passive way as a background application in contrast to TV (additional services such as slideshows loose its benefits under this aspect) / Nationwide radio stations don't make sense, since people want to listen to local content of their city / Old technology of FM is a well operating global standard of mass media, which is why it is difficult to be replaced (/ the switch from DAB to DAB+ was not an issue, since barely anybody did listen to DAB) / People had to pay 50€ for something they already have (currently with some broadcasting stations, they would even get less, since no local content is provided) / listeners don't care about the technology of distribution (it could be webstreaming, mobile internet, terrestrial with FM or DAB, cable, …) / it took too long	/ No benefit since the use case is a passive one to listen absent-mindedly to the radio in the background / missing marketing / The old technology is too good / A higher quality is not perceived / Too expensive for not having a benefit	missing benefit
		ContentPlay	a distribution method for radio	.-	Dualism for digital with IP and DAB	/ radio should be easy, enjoyable, automatic as an iPhone app / hybrid receivers with FM, IP and DAB / a governmental institution as driving force / industrial cooperation: "Yes you need to have an industry that is talking to each other and you need to have leadership from somewhere. It doesn't have to be the Government…"	/ meta data (wheather information, football information) but corrently not / images	additional services	.-	that message hasn't been perceived	developing a user experience that will allow that audio content arrives in different ways	… is a hybrid, intelligent radio using FM, IP and DAB. The things need to be flexibel. Within the next ten years, there is still a 1-to-N distribution needed.	In 15 years it's possible that most sound broadcasting will be over the internet by then to mobile devices, but the problem of providing data to millions still has to be solved.	/ not much time taken on the user experience of DAB / it's not a good marketing tool for radio stations / A lot of DAB receivers are not easy to use or pretty to look at compared to e.g. an iPad / it is a hard time for the listener deciding between FM and the internet AND DAB / National broadcasting doesn't satisfy the need for local content / DAB cannot be updated: "And the kind of codex that DAB use have been updated now. We did not build into DAB in our flexibility. You cannot do over the air software updates to put a new codex in to your radio. You are stuck with the original MP2 codex from 1985." / Not enough spectrum used for additional service and images, which is why the perception still is old-fashioned (chicken and egg problem: there are also no receivers being able to display it) / SPEED: "So if we had moved very quickly and one thing (…) when you're innovating, speed is everything because you have, the world is still turning underneath you (…) you are building your thing but the world is still turning."	/ Difficulty in learning compared to known behaviour / Cost of infrastructure / no possibility of updating DAB / Diffusion too slow / other technology alternatives / No governmental push / lack of industrial cooperation / no added value	no added value
		IT infrastructure	/ putting transmission under a digital format such as in other industries / having audio-centric content enriched with multimedia (visual & text based)	/ Users of media, that have a strong relationship to the brand of the radio station. / listeners to cultural programs with further explanations with additional information	/ topic has been around for 20 years / low adoption rate compared to other technologies: "the adoption rate for analogue film shooting to digital cinema, the conversation rate, which is about 70% of shooting today is done on digital cinema.(…) look at the amount of listeners, or the amount of producers that produce in the context of digital radio, that amount is still very, very low"	/ cheap receivers / a lot more programs / technology needs to be very relevant to make people to buy as they do with smartphones	/ context specific information / could be saved and replayed later on to get more information	media-enrichment	marketing was focused on the transmission made by the people in charge of the transmission: marketing has been focused on choice, which was not important	/ broadcasters are very cautious about this aspect / only very well informed people would understand the green aspect of it	Marketing should be performed by people being programme oriented.	. . . in smartphones. One day it may be an obligation to have receiver chips incorporated into smartphones for security reasons. FM could be received enriched by IT service. (as hybrid radio)	A substitution of DAB is rather by technologies incorporated in smartphones. It could be a combination of terrestrial (FM or DAB) sound broadcasting and internet connection as mash-up approach.	/ radio listeners are much more connected to their station than people watching TV (the use of additional channels is questionable) / Before 2011 no nationwide broadcasting: "something totally new for Germany in the radio space because of the way that politics and histories of Germany broadcasting did not provision for a nationwide signal" / The adaptation of the devices to receive digital is very expensive compared to TV, where the ratio for a DVB-T adopter to the TV is ok. / No relevance to buy in comparison to TV receivers: "…in TV, if you move from five to 25 programmes you are relevant to the people who like to consume a lot of television. In radio if you just allow maybe more comfortable listening because of less interference, it's not very clear that the people understand the value." / Power of organization: people in charge of transmission have a very tactical tool in hand to be able to control where broadcasting happens. It should have been people being programme oriented. / Other type of media (TV/internet) has a broader offer, since it touches more senses. / Rivalry and fear of competition, since with a multiplex smaller stations may get bigger and endanger the positon of the existing stations.	/ missing added values: " In radio if you just allow maybe more comfortable listening because of less interference, it's not very clear that the people understand the value." / lack of marketing - done by people coming from Digital TV: "marketing has been focused around something which has not been very, very important. Therefore most of the people that look at the marketing of the digital radio do not understand why it would be interesting for them." / Cost of switching is too high: "that's our experience of business that the cost to acquire is too high versus the value, too specific but not enough" / Compatibility concerning other networks to be incorporated / technology-driven, not focused on end user (listener)	not enough appeal to the user / too. Technical
		TransManu	Digital radio are radio programmes broadcasted t in a digital file format. (terrestrial, satellite or cable)	Different kind of listeners, e.g. those interested in high quality sound and car drivers who cross distance and want to hear to one station.	Currently there is some momentum for having a network in addition to the analogue, but there are only very few receivers in the market: "So it was only for people really knowing that there is DAB in the air. Nobody else knew it and so it was not quite popular."	/ switch off date for the old FM technology / Car industry as facilitator: "the car industry could push that a bit more, because the cars are the only devices which are replaced regularly."	/ Programme information / cover of the song / further additional information	Information about the current song	No strong marketing in Germany: "…as the IFA was taking place, there was some advertising for DAB for some channels of the public broadcasters. But it's not heavily marketed in Germany, I would say."	Listeners don't care about that.	The benefits should be made clearer to the customer. A focus on sound quality only is wrong, but traffic information would help as being a benefit.	… is mobile internet but not only for Sound also for TV: "… any kind of IP distribution, both via LTE or wireless LAN, or any mobile standard which is out there"	IP technologies as clear technology substitution for DAB: "it's not easy to really replace FM, and to compete with an IP distribution, because I think this is the next threat"	/ "It's difficult to replace (…) the old FM networks in Germany, because there are (…) 350 million FM receivers in the market." / Difficulty of propagating switch off of the old FM in favour of DAB since individuals had to buy new receiver devices. / Sound quality is not necessarily an added valued: "Because driving in the car, you have so much different noises around you, I think the quality and some distortions in the signal are not that important to most of the listeners" / More innovative technologies are already existing: " If you want to have a digital DAB receiver or a, let's say LTE capable device, which can receive your Spotify or any other music platform content, then at least the young people would rather go for the LTE technology because you have more possibilities with that." / Small governmental interaction since sales of FM frequencies is not lucrative.	/ High complementarity of FM as technology regarding receivers in market / Later technology is already available / Higher quality not perceived as added value / technology substituion with internet based technologies sucha as LTE capable devices existing in parallel to the old technology of FM / high infrastructure costs for network providers / no contagion: Low receiver population in the market	Most critical: availability of even newer internet technologies
	sting Infras	NetProv	Infrastructural substitution of old analogue FM technology	A new generation expecting a big choice due to what internet technologies have been providing.	Unfortunately, this is a catch-22 (chicken&egg problem), since meanwhile the infrastructure is set up but the receivers e.g. in automobiles have been to expensive so far (about 500€) / rather early adopters are interested	interactivity and integratability with upcoming internet possibilities of new electronic devices -> dualism / coordination of all players (equipment manufacturers, infrastructure providers, content creation, car manufacturer) / complementarity with upcoming trends (LTE technology in new devices)	Reception of the same content all over Germany on individual listener interest / Possibility of providing a more competitive advertisement business since the current status quo situation can be extended by new business cases on industry level / with more diversity (more channels) target group specific advertisement can be a benefit for the advertisement business	More choice	none - no conscious perception of marketing so far / rather background discussions whether this technology is needed or not	This is only nice to have - not a buying argument / people would not care that much - therefore it is not relevant	Go back in time and think of how to satisfy upcoming infrastructure needs first, before launching a technology.	… still is terrestrial due to efficient frequency use for 1-to-N. / complementarity needed for other upcoming technologies such as LTE incorporated into electronic equipment / the willingness to pay for radio is towards zero, / Due to a multi-use of media in upcoming generation, there is a high probability of a co-existence of linear (broadcast, e.g. DAB+) and individualized (internet) media distribution	unsure, since it would require a business case for telecommunication provider (this is difficult since the average spending for telco is constant / intelligent linking of IP-world and broadcast world would be the future	The different industries initially only followed very different interests partially contradicting - This is why the initial introduction of DAB failed! / It was romoted as "higher quality sound" but due listener experience trend was towards old technology FM since its perception was of higher quality / It was supposingly not a technological challenge but rather to prepare and find added value in the ecosystem / Content was missing when infrastructure and receiver where there / no governmental switch-off decision as in other countries	lobbiism at start with big criticism / no coordination of all players of different industries / no higher performance in quality perceived in comparison to the old technology FM / no clear governmental direction as in other countries / no awareness of magical triangle (four sides) with socio-economics, business case, technological performance AND content	industry collaboration (equipment manufacturers, infrastructure providers, content creation, car manufacturer) / business case diversity apart from technological aspect
		ChipManu	Providing digital radio - especially radio - still is a uni-directional information flow	car owners	More communication between stakeholders in Germany since 2011 due to lessons learnt before	cooperation with retailers especially focusing on training the sales staff / European wide reception focusing on increasing mobility with cars - This makes it work across borders / strong governmental support on European level	easiness of listening since no tuning needed / additional graphics of the service/station / additional information such as wheather	no tuning	too low marketing activity. No marketing to masses	You need to bring the consumers to the shops where there are good receivers for sale.	This argument is not used in promoting digital radio (partially due to stakeholder interests) / Challenge of explaining the infrastructure complexity to save energy / There is the chance of using this argument to make it receiveable as green.	… a co-existence of IP and terrestrial broadcasting. A Merge of IP and digital radio is possible. Hybrid radio is supporting the advantage of digital radio, since it is easier to combine several digital technologies in comparison to combine analogue with digital technologies.	There are a lot of discussions about IP, but a co-existence is rather likely.	Historically broadcasters were not interested to discuss with receiver makers / Stakeholders as retailers were forgotten to talk to when planning the introduction (you also need to train them) / FM is very popular and the usability of FM is well known. Everybody is aware of it, therefore a new technology struggles. / there is the need to inform masses and communicate that it's future-proof with addititional services and not only focussing on the technology itself "having promotion for digital radio without having the retailers informed, which was the case, and without having attractive products into the shops, which was the case, (…) it would also not create a market." / fight between one technology and the next technology (latest between IP and digital radio) used to change the direction or to cause a delay. / discussions about IP is confusing consumers	missing industry collaboration / missing training of sales staff at retailers (arguments regarding added value) and thus consumers / behaviour with old technology is widely established and difficult to change / no contagion within the mass / bad/no marketing / no higher performance perceived (initially bad receivers in the shops) / community is towards the older technology (status-quo, perceived as threat) / leap-frogging / diversity of (media) laws across regions (governmental support needed) / complexity of the infrastructure regarding cost savings	lack in communication to the masses and between stakeholders
		CarManu	"1toN" network with DAB, DAB+ or DMB	Those who desire high quality and new content / digital fetischist	beginnining, tendency of growth, but chicken-egg problem	better quality / same price (currently: 5€ FM vs. 50€ DAB)	theoretically more content and additional information (but not provided for a long time)	more services as meta data on genre etc.	too weak, not perceived / open questions remained about benefit / very slow process	doubts about that / attempt to promote factor 6 (but only on transmitter site !!!)	to market the perceivable added values / not to communicate problems only	hybrid - it is very probable to have hybrid structures for broadcasting and telecommunication because of bandwidth.	Somewhen, LTE might have a specification with 1-to-N as "LTE Broadcast"	Million investments already done for DAB. Concerns since it would require the same for DAB+. (It was a big discussion when DAB+ was introduced, since all had to be changed due to a lack of compatibility to DAB+ with high costs.) / Individuals, who purchase a car expect to be able to use the receiver technology for 10 years. Unfortunately, DAB receivers are not compatible with DAB+. Now the barely can receive anything. / Bad relationship of benefit to price for consumers / Apart from the costs of DAB receivers, the old technology is still very good. / slow development (small take rates) / development too technology-focused / lack in marketing / missing governmental signals	missing benefit / no speed to market / no contagion / lack in marketing / status quo of organizations / expensive development	good performance of old technology FM / missing differentiation (missing benefit)
	Receiver Manufacturers	RecManu	Digital radio as perception of radio stations in a digital form (DAB+, internet or other technologies)	In principle all social groups from youngsters (listening pop), older (e.g.Rock) and more major (church radios) / Nevertheless, Radio is a medium used by more major people (youngsters are not as active with radio as up-40s but with internet usage as youTube and Facebook)	Well, DAB+ was relaunched in 2011. Hopefully it is not going to be a FLOP again as DAB was one or two years before. / A lot of people just don't know it. (This is the lesson-learnt by retailers, purchasers and decision makers)	Avoiding a chicken-egg problem. The parties of equipment manufacturer and content provider should communicate and be in line from the beginning. / The interface to the consumer (retailers, stores) should be part of the decision progress from the beginning	no more tuning / more choice / not necessarily the quality	more choice	no marketing perceived before job with the technology / discussions engaged by the ministry of economy in early 2011 as starting point of how to market the technology	no chance for green perception / so far not promoted / should be communicated linked to infrastructural savings	more communication via retailers	digital (there will be more receivers by brands such as Samsung and Sony) in the short-run. / In the longrun, FM will probably be switched off (ideally)	unlikely, but there might be new services and therefore it would be important to have receivers which could be updated	Youngsters are not as active with radio as up-40s due to their interest in media consumption via internet as youTube and Facebook / DAB was a FLOP since nobody knew it. / Chicken&Egg problem: "The industry says: Why should we produce receivers, since there is no content whereas the broadcasting stations claimed, that it didn't make sense start broadcasting without sufficient receivers in the market." / For years, difference stakeholders were distracted by claiming the faulty movements are of the other stakeholders. / Retailers should have been very early in the process to communicate to consumers but were not! / young consumers expect equipment to be updateable due to new services (future-readiness)	No Industrial cooperation and communication / Added values are difficult to be perceived / No clear governmental decision / no contagion & bad marketing communication / young generation with focus on internet-based technologies	Consumers struggled to understand the benefits of the new services
		StandForum	digital radio based on the DAB family of standards	young / curious / future thinking	varies by country / progress has being made certainly in Australia and the UK / Germany is very much at the start	"for the launch and roll-out of digitial radio to be successful, industry collaboration is key" / product demonstration in retailers as MediaMarkt with a good DAB signal (currently: a lot of washing machines and a bad DAB signal)	no tuning and no fading resulting in more simplicity and a better quality and more choice (this is proven in the UK)	quality	unsure about germany, but in the UK publicity campaign	doubts about reduced energy consumption / listeners wouldn't care	promotion acrosss industries to make people get aware of an industry collaboration (*)	hopefully DAB plus (maybe some doubts)	some competing possibilities and their supporters to talk the talk / internet may not have sufficient capacity to handle the volume of listening.	Missing industry collaboration (receiver, transmitter manufacturers, car industry, retailers, radio stations) / partially too early and only regionally (Bavaria) / Reception problems with receivers of the older technology of DAB (receivers not working with new standard) "… you'll have some people with an older receiver that will not be capable of receiving DAB Plus." / missing perception possibilities in retailers / in Germany, private and public broadcaster should have collaborated earlier	missing industry collaboration / missing adaptability of receivers / missing perception possibilities in retailers / Lobbyism of other technologies	Missing industry collaboration (receiver, transmitter manufacturers, car industry, retailers, radio stations)
		RadioFutur	A new plafform for radio with DAB, DRM, internet radio and radio via TV	any listeners that enjoys radio	The status is diverse depending on the country. Germany has decided for DAB plus. Norway is interesting … certainly going further than any other country is going now (because in Norway it costs too much to run so many FM transmitters)	communicating additional choice and not more quality / in the past, there were very new brands with a lot of advertising (nobody tunes in) but it would be better to have additional choice from exising brands that people know. / It is important that governments get involved since public broadcasters won't do anything until they are asked to (private stations need commercial inducement as useful help) ==> as in Norway cost of infrastructure	more content / easier to tune in (no need to remember numbers or frequencies)	additional choice	diverse marketing campaigns / not to familiar with the marketing in Germany	doubts whether it is greener / nobody cares about it	improve concepts for advertising possibilities of radio stations to have financial motiviation	… depending on the developments of internet technologies. Internet offers benefits of interaction, which Broadcast doesn't. Nevertheless, hybrid radio is important for the next years, since people don't care the technological reception media: "…have a look at hybrid radio. The concept of actually from a user's point of view forgetting whether they are tuned in on FM or DAB or the internet, it doesn't actually matter. "	no complete substituion of broadcast (FM, DAB) over the next 10 years, since pure telecommunication cannot offer the needed data rates for millions of people.	DAB offers more choice, not necessarily because it offers you a better service than FM / … where we have gone wrong in the past is we have talked about audio quality, sound quality and the reality is that nobody cares about sound quality. / in the past, there were very new brands with a lot of advertising (nobody tunes in) but it would be better to have additional choice from exising brands that people know. / people were obviously quite happy with the radio stations that they were tuning into. / looking at what the internet offers… / chicken&egg situation / DAB and DAB+: with an old DAB receiver, they would not work outside the UK: "…if you buy an old DB receiver, if you can still find one then yes that won't work outside of the UK and I think that is it now. " / one benefit of radio generally is because of listeners being creatures of habit (people see no reason to upgrade) / no clear governmental push	/ public broadcasters may be towards the old technology / no higher utility perceived when focusing on one existing station / leap-frog technology in sight / no change in current behaviour/habit / no governmental decision or push unlike in Norway GERMANY / no reception = no perception possible / governmental constraints (no national radio)	people are happy with the old technology (goes slowly)
		RadioConsu	with additional services more than just classic radio	all kind of listeners due to its nature as mass market application	several alternatives to digital radio with DAB/DAB+ are available, which is why only hybrid digital radio can be successful / in Germany there is a lot of radio listening in cars / in Europe ther would be DAB in some point in time	/ free to listen / wide coverage / range of devices / good audio quality / new services / cheap receivers	spectrum efficient resulting in more channels resulting in more choice	more choice	efforts to explain that there is more functionality than with classic FM	No	more focus on interactivity e.g. text information, but there are things listeners don't understand yet which is difficult to promote. / communicate the four benefits: easier to use, more channels, text information, less interference	… with other platforms. Other platforms apart from DAB/DAB+ are apps for mobile phones using IP streams, radio over TV and internet platforms	as mass market application, IP streaming only would not be the technology substituion for terrestrial sound broadcasting	a lot of radio listening in cars with a need of getting manufacturers on board / Since in comparison in the UK there are only four big commercial radios, Germany's situation is difficult since a lot of private commercial radios need to be on board to push the technology / regional public broadcasters in Germany don't make it easy to solve problems that effect the whole industry / initially tried to promote it on improved sound quality, which didn't work that well / public service broadcasters were not promoting it and not providing new conten (simulcast) / rivalry between public and commercial broadcasters (no cooperation) / DAB radios don't support DAB+: "So DAB Plus receivers work on DAB and DAB Plus. The DAB radios will only do DAB, but there's, that's a legacy issue."	/ difficult industry structure (investment too big for commercial radios) / lack in marketing / missing cooperation between public and commercial broadcasters (local rivalry-status quo) / missing aid in investment regulation for technolog decision of private broadcasters / receivers are too expensive	wrong marketing with focusing on quality having the need for promoting other advantages
	Radio & Broadcasting Expert Group	InfraServiceAUS	Transition to a digital transmission system to offer certain benefits to the listening customer	That's the big challenge: Those listeners, whose mindsets can be changed	Diverse and depending on the country. - DAB+ in Australia following the UK - no information about Germany	Success factors of UK and Australia: - Bringing together all radio stations - Saving costs with a common approach - Clear business case offering: "We can take you digital for far less money or investment costs than you could do yourself" Special success factors of Germany: no information	/ clearer sound / extra data program / content	clearer quality & more channels	/ TV advertising / advertising spots in FM radio / adverts in newspapers	No information on that	Australia: good marketing already Germany: no inormation on that	…with FM. / FM remains always: "FM will remain a peer, always a peer to DAB." / DAB may be deployed additionally in more rural areas.	This depends on the country: In countries with high population density, IP streaming will take over, but most likely not in Australia	/ challenge of changing the listeners' mindsets, since "FM typically works well enough" / Coverage is missing / Chicken & Egg problem: First listening public is needed for a later expansion of networks / Lower GDP countries would not have access to the funding for an additional sound broadcasting format	/ Old technology is still too good (it's sound quality is acceptable) "And of course the FM will still be here for many many many years to come." / Critical mass is not achieved as in many other countries	Worldwide replacement of an old Technology

Figure I-1 – Initial unordered meta-matrix: Aspects of digital radio

			3		4		5			6		7		8		
			Understanding of "Digital Radio"	Kind of Listeners	Current Status	Success Factors	Advantage of Digital Radio	Important added value	perceived marketing so far	Chance for perceiving as greener	suggested improvement for marketing technology	Future of Radio is . . .	future technology substitution of DAB	Difficulties for the Diffusion	Diversity of barriers for the Diffusion	Most important barrier
Area		Interviewee														
		ModeratorDAB												/ perception that receivers are only among people working in the broadcasting industry / years ago it was a new technology, now this dynamics is low / advantages of the technologies got lost in the years: "… can't see any advantages for having a new digital broadcast device!!" / unsuccessful marketing / simulcasting at the beginning did not create added value with an additional program: "…at least in the very beginning there was never any such a program."	/ missing benefit: "… it hasn't achieved in showing people that it's something better than normal FM radio." / diffusion too long (added values not available any more) / marketing without any impact / good old technology: "We need the old technology, if we don't get the old technology the whole radio will fail." / not better than FM / old technology: "on the one hand it's modern, on the other hand it seems very old fashioned." / contagion - people don't know about it / no need for an expensive transmitter / lack of governmental support in shut-down FM	missing marketing is reason that only few people know about it: "It wasn't like a big bang or (…) something really big has happened in radio technology"
		ExModMarketer												/ One problem lies in the receiver business: "We've no really good products in the field of digital audio broadcasting." / Too expensive: "I have not the chance for some more money to get the DAB in my car" / Not in the focus of technology enthusiasts: "It's early adopters which are using new technologies and bring these to the mass of the market. (...) just one look to Google, then you will see, it's a 20 years old technology (...) it's the wrong product for people who love trends and to be a techie." / Only regional initiatives at the beginning: "it was just the state of Bavaria who made some efforts to push this DAB project." / no industry pushes: "there was no effort from industry at this time" of introduction / lack of information and problem of branding: "...the most people I think, if you are listeningto DAB, the most people think it's web radio." / It has to be explained what the benefit of it is.	/ benefit is not that obvious / no marketing / old technology compared to what is available with ipods and smartphones	contagion / alternatives
		EdModContent												/ price for receivers (FM: 3€ vs. DAB: >80€) / no big market for special content / quality was bad at the beginning and as consequence people listened CD or FM (in contrast to marketing slogans) / with the first DAB programs, there was not more choice (in contrast to marketing slogans) ==> no proofing, convincing and explaining added value / there was no demand at all for a better quality among people / conceptual error having a technology focus but not a focus on end user needs / DAB receivers buyer got dispeased when DAB+ was introduced / biggest marketing error: First DAB stations were offered FM frequencies to have the possibility of promoting the technology via FM ==> added value of different content got destroyed (very absurd: to market one medium with content via another medium with the same content!!)	/ price / behavioral change needed / no benefit/added value (neither for listener nor for industry e.g. car manufacturer) / FM technology already satisfies needs of people / lack in marketing (big errors) / quality worse compared to FM / diverse interests of stakeholders (difficulties in industrial cooperation)	/ technology push not focused on end user at all / marketing error, which eliminated added value of different content
		AdvSalesMana												"Why switch to that technology" as leading question for both listeners and industrial stakeholders: / supposed to have better quality but the perception of listeners was not like that (especially in the countryside), since they couldn't hear the difference in quality / no awareness has been generated / for radio stations there have not been possibilities to earn money in 12 years / Since radio stations needed to have content to get licences thinking "maybe it is the future", they initially did use computers for a 24/7 playlist (now its only simulcast) / no one uses additional features due to internet as substitute / receivers are too expensive (automotive did not put receivers as standard and not all cars have it)	/ no benefits can be perceived (quality, services, choice) / missing contagion / substitute technology available / receiver costs are too high (40-80€) / no governmental pressure / limit in availability (cars) / technology substitute availabe with smartphones	internet as competing technology for the services being exactly those aspects which were the benefits some years ago
	Studio & Radio Stations	EdMediaMana												Rather a conceptional problem: / People listen to radio in a passive way as a background application in contrast to TV (additional services such as slideshows loose its benefits under this aspect) / Nationwide radio stations don't make sense, since people want to listen to local content of their city / Old technology of FM is a well operating global standard of mass media, which is why it is difficult to be replaced (/ the switch from DAB to DAB+ was not an issue, since barely anybody did listen to DAB) / People had to pay 50€ for something they already have (currently with some broadcasting stations, they would even get less, since no local content is provided) / listeners dont care about the technology of distribution (it could be webstreaming, mobile internet, terrestrial with FM or DAB, cable, ...) / it took too long	/ No benefit since the use case is a passive one to listen absent-mindedly to the radio in the background / missing marketing / The old technology is too good / A higher quality is not perceived / Too expensive for not having a benefit	missing benefit
		ContentPlay												/ not much time taken on the user experience of DAB / it's not a good marketing tool for radio stations / A lot of DAB receivers are not easy to use or pretty to look at compared to e.g. an iPad / it is a hard time for the listener deciding between FM and the internet AND DAB / National broadcasting doesn't satisfy the need for local content / DAB cannot be updated: "And the kind of codex that DAB use have been updated now. We did not build into DAB in our flexibility. You cannot do over the air software updates to put a new codex in to your radio. You are stuck with the original MP2 codex from 1985." / Not enough spectrum used for additional service and images, which is why the perception still is old-fashioned (chicken and egg problem: there are also no receivers being able to display it) / SPEED: "So if we had moved very quickly and one thing (…) when you're innovating, speed is everything because you have, the world is still turning underneath you (…) you are building your thing but the world is still turning."	/ Difficulty in learning compared to known behaviour / Cost of infrastructure / no possibility of updating DAB / Diffusion too slow / other technology alternatives / No governmental push / lack of industrial cooperation / no added value	no added value
		IT infrastructure												/ radio listeners are much more connected to their station than people watching TV (the use of additional channels is questionable) / Before 2011 no nationwide broadcasting: "something totally new for Germany in the radio space because of the way that politics and histories of Germany broadcasting did not provision for a nationwide signal" / The adaptation of the devices to receive digital is very expensive compared to TV, where the ratio for a DVB-T adopter to the TV is ok. / No relevance to buy in comparison to TV receivers: "...in TV, if you move from five to 25 programmes you are relevant to the people who like to consume a lot of television. In radio if you just allow maybe more comfortable listening because of less interference, it's not very clear that the people understand the value." / Power of organization: people in charge of transmission have a very tactical tool in hand to be able to control where broadcasting happens. It should have been people being programme oriented. / Other type of media (TV/internet) has a broader offer, since it touches more senses. / Rivalry and fear of competition, since with a multiplex smaller stations may get bigger and endanger the positon of the existing stations.	/ missing added values: " In radio if you just allow maybe more comfortable listening because of less interference, it's not very clear that the people understand the value." / lack of marketing - done by people coming from Digital TV: "marketing has been focused around something which has not been very, very important. Therefore most of the people that look at the marketing of the digital radio do not understand why it would be interesting for them." / Cost of switching is too high: "that's our experience of business that the cost to acquire is too high versus the value, too specific but not enough" / Compatibility concerning other networks to be incorporated / technology-driven, not focused on end user (listener)	not enough appeal to the user / too. Technical
		TransManu												/ "It's difficult to replace (…) the old FM networks in Germany, because there are (…) 350 million FM receivers in the market." / Difficulty of propagating switch off of the old FM in favour of DAB since individuals had to buy new receiver devices. / Sound quality is not necessarily an added valued: "Because driving in the car, you have so much different noises around you, I think the quality and some distortions in the signal are not that important to most of the listeners" / More innovative technologies are already existing: " If you want to have a digital DAB receiver or a, let's say LTE capable device, which can receive your Spotify or any other music platform content, then at least the young people would rather go for the LTE technology because you have more possibilities with that." / Small governmental interaction since sales of FM frequencies is not lucrative.	/ High complementarity of FM as technology regarding receivers in market / Later technology is already available / Higher quality not perceived as added value / technology substituion with internet based technologies sucha as LTE capable devices existing in parallel to the old technology of FM / high infrastructure costs for network providers / no contagion: Low receiver population in the market	Most critical: availability of even newer internet technologies
	sting Infras	NetProv												The different industries initially only followed very different interests partially contradicting - This is why the initial introduction of DAB failed! / It was romoted as "higher quality sound" but due listener experience trend was towards old technology FM since its perception was of higher quality / It was supposingly not a technological challenge but rather to prepare and find added value in the ecosystem / Content was missing when infrastructure and receiver where there / no governmental switch-off decision as in other countries	lobbiism at start with big criticism / no coordination of all players of different industries / no higher performance in quality perceived in comparison to the old technology FM / no clear governmental direction as in other countries / no awareness of magical triangle (four sides) with socio-economics, business case, technological performance AND content	industry collaboration (equipment manufacturers, infrastructure providers, content creation, car manufacturer) / business case diversity apart from technological aspect
		ChipManu												Historically broadcasters were not interested to discuss with receiver makers / Stakeholders as retailers were forgotten to talk to when planning the introduction (you also need to train them) / FM is very popular and the usability of FM is well known. Everybody is aware of it, therefore a new technology struggles. / there is the need to inform masses and communicate that it's future-proof with addititional services and not only focussing on the technology itself "having promotion for digital radio without having the retailers informed, which was the case, and without having attractive products into the shops, which was the case, (...) it would also not create a market." / fight between one technology and the next technology (latest between IP and digital radio) used to change the direction or to cause a delay. / discussions about IP is confusing consumers	missing industry collaboration / missing training of sales staff at retailers (arguments regarding added value) and thus consumers / behaviour with old technology is widely established and difficult to change / no contagion within the mass / bad/no marketing / no higher performance perceived (initially bad receivers in the shops) / community is towards the older technology (status-quo, perceived as threat) / leap-frogging / diversity of (media) laws across regions (governmental support needed) / complexity of the infrastructure regarding cost savings	lack in communication to the masses and between stakeholders
		CarManu												Million investments already done for DAB. Concerns since it would require the same for DAB+. (It was a big discussion when DAB+ was introduced, since all had to be changed due to a lack of compatibility to DAB+ with high costs.) / Individuals, who purchase a car expect to be able to use the receiver technology for 10 years. Unfortunately, DAB receivers are not compatible with DAB+. Now the barely can receive anything. / Bad relationship of benefit to price for consumers / Apart from the costs of DAB receivers, the old technology is still very good. / slow development (small take rates) / development too technology-focused / lack in marketing / missing governmental signals	missing benefit / no speed to market / no contagion / lack in marketing / status quo of organizations / expensive development	good performance of old technology FM / missing differentiation (missing benefit)
	Receiver Manufacturers	RecManu												Youngsters are not as active with radio as up-40s due to their interest in media consumption via internet as youTube and Facebook / DAB was a FLOP since nobody knew it. / Chicken&Egg problem: "The industry says: Why should we produce receivers, since there is no content whereas the broadcasting stations claimed, that it didn't make sense start broadcasting without sufficient receivers in the market." / For years, difference stakeholders were distracted by claiming the faulty movements are of the other stakeholders. / Retailers should have been very early in the process to communicate to consumers but were not! / young consumers expect equipment to be updateable due to new services (future-readiness)	No Industrial cooperation and communication / Added values are difficult to be perceived / No clear governmental decision / no contagion & bad marketing communication / young generation with focus on internet-based technologies	Consumers struggled to understand the benefits of the new services
		StandForum												Missing industry collaboration (receiver, transmitter manufacturers, car industry, retailers, radio stations) / partially too early and only regionally (Bavaria) / Reception problems with receivers of the older technology of DAB (receivers not working with new standard) "… you'll have some people with an older receiver that will not be capable of receiving DAB Plus." / missing perception possibilities in retailers / in Germany, private and public broadcaster should have collaborated earlier	missing industry collaboration / missing adaptability of receivers / missing perception possibilities in retailers / Lobbyism of other technologies	Missing industry collaboration (receiver, transmitter manufacturers, car industry, retailers, radio stations)
		RadioFutur												DAB offers more choice, not necessarily because it offers you a better service than FM / … where we have gone wrong in the past is we have talked about audio quality, sound quality and the reality is that nobody cares about sound quality. / in the past, there were very new brands with a lot of advertising (nobody tunes in) but it would be better to have additional choice from exising brands that people know. / people were obviously quite happy with the radio stations that they were tuning into. / looking at what the internet offers… / chicken&egg situation / DAB and DAB+: with an old DAB receiver, they would not work outside the UK: "…if you buy an old DB receiver, if you can still find one then yes that won't work outside of the UK and I think that is it now." / one benefit of radio generally is because of listeners being creatures of habit (people see no reason to upgrade) / no clear governmental push	/ public broadcasters may be towards the old technology / no higher utility perceived when focusing on one existing station / leap-frog technology in sight / no change in current behaviour/habit / no governmental decision or push unlike in Norway GERMANY / no reception = no perception possible / governmental constraints (no national radio)	people are happy with the old technology (goes slowly)
		RadioConsu												a lot of radio listening in cars with a need of getting manufacturers on board / Since in comparison in the UK there are only four big commercial radios, Germany's situation is difficult since a lot of private commercial radios need to be on board to push the technology / regional public broadcasters in Germany don't make it easy to solve problems that effect the whole industry / initially tried to promote it on improved sound quality, which didn't work that well / public service broadcasters were not promoting it and not providing new conten (simulcast) / rivalry between public and commercial broadcasters (no cooperation) / DAB radios don't support DAB+: "So DAB Plus receivers work on DAB and DAB Plus. The DAB radios will only do DAB, but there's, that's a legacy issue."	/ difficult industry structure (investment too big for commercial radios) / lack in marketing / missing cooperation between public and commercial broadcasters (local rivalry-status quo) / missing aid in investment regulation for technolog decision of private broadcasters / receivers are too expensive	wrong marketing with focusing on quality having the need for promoting other advantages
	Radio & Broadcasting Expert Group	InfraServiceAUS												/ challenge of changing the listeners' mindsets, since "FM typically works well enough" / Coverage is missing / Chicken & Egg problem: First listening public is needed for a later expansion of networks / Lower GDP countries would not have access to the funding for an additional sound broadcasting format	/ Old technology is still too good (it's sound quality is acceptable) "And of course the FM will still be here for many many many years to come." / Critical mass is not achieved as in many other countries	Worldwide replacement of an old Technology

Figure I-2 – Unordered meta-matrix subset: Diffusion challenges for digital radio

Cluster for diffusion barrier mentioned	Diffusion problem mentioned	Illustrations
no diffusion achieved	existence of diffusion problem, no break-through of the technology	20 years without progress: "I was really in the mind-set that it's a brilliant technology and we get DAB in the next month (...) But 20 years later we see that we have nearly no DAB" (ExModMarketer) The view from 1999 was that it would be the "future of radio", but nothing happened. (EdMediaManager) 1990s until 2012: no diffusion, plan for switch-off is postponed (not much hope) (EdModContent) Rather early adopters are interested. (NetProv) Well, DAB+ was re-launched in 2011. Hopefully it is not going to be a FLOP again as DAB was one or two years before. A lot of people just don't know it. (RecManu) Diffusion varies by country: Germany is very much at the start compared to other countries. (StandForum) DAB only stations realize that without FM frequency, they would not have success. They realize that digital sound broadcasting is not going to work. (ModeratorDAB) Low adoption rate compared to other technologies: "the adoption rate for analogue film shooting to digital cinema, the conversation rate, which is about 70% of shooting today is done on digital cinema.(...) look at the amount of listeners, or the amount of producers that produce in the context of digital radio, that amount is still very, very low" (ITinfrastructure)
Missing inter-industrial collaboration (chicken and egg problem)	Difficulty in solving a chicken&egg problem, often related to a missing collaboration between different industries	Missing industry collaboration (receiver, transmitter manufacturers, car industry, retailers, radio stations) (StandForum) Chicken&Egg problem: "The industry says: Why should we produce receivers, since there is no content whereas the broadcasting stations claimed that it didn't make sense start broadcasting without sufficient receivers in the market." (RecManu) Stakeholders as retailers were forgotten to talk to during technology introduction. (ChipManu) Content was missing when infrastructure and receivers where there. (NetProv) No driving, cooperating forces exist: "Yes you need to have an industry that is talking to each other and you need to have leadership from somewhere. It doesn't have to be the Government..." (ContentPlay) Missing cooperation between public and commercial broadcasters due to local rivalry is not supporting. (RadioConsu) Public broadcasters have been towards old technology and therefore were not pushing for it (RadioFutur) schedules need to be coordinated to incorporate suitable receivers in new cars (CarManu)
lack of marketing	No perception achieved by communication strategy, Conceptual marketing errors made with the consequence of destroying benefit	Open questions remained about the benefit of it (CarManu) There is still the need to inform masses and communicate that it's future-proof with additional services and not only focusing on the technology itself. "Having promotion for digital radio without having the retailers informed, which was the case, and without having attractive products in the shops, which was the case, (...) it would also not create a market!" (ChipManu) Big marketing mistake of destroying added value of additional choice since "First DAB stations were offered FM frequencies to have the possibility of promoting the new technology via the old technology." (EdModContent) There hasn't been any marketing: "I can't remember one big marketing campaign!" (ModeratorDAB) Marketing done by people coming from Digital TV: "marketing has been focused around something which has not been very, very important. Therefore most of the people that look at the marketing of the digital radio do not understand why it would be interesting for them." (IT infrastructure)
		...

missing recognition	Nobody knew about it, slow mouth-to-mouth communication	No awareness has been generated: "even within the radio station, people are asking what is DAB and what are the benefits?" (AdvSalesMana) Slow development: "small take-rates" (CarManu) First technology was not at all known: "DAB was a FLOP since nobody knew it." (RecManu) Low sales numbers for a mass product (RecManu) Diffusion too slow, "while the world is turning" (ContentPlay) Perception that receivers are only among people working in the broadcasting industry. It meanwhile is an old technology, the diffusion took too long. The added values not available any more: "on the one hand it's modern; on the other hand it seems very old fashioned." (ModeratorDAB)
missing benefit and no added value	Quality as selling argument was not perceived better as old technology	Quality was bad at the beginning. No benefit could be perceived. (EdModContent) No benefit of additional services since the actual use case is listening very passively and absent-mindedly. A higher quality is not perceived. (EdMediaMana) Perception of listeners concerning sound quality was worse than before. No usage of additional services (AdvSalesMana) Technology was sold having a higher sound quality but people didn't care about that. No higher utility perceived when focusing on one station. (RadioFutur) This is something they already have and with some stations they would even get less. (EdMediaMana) No higher performance with quality perceived in comparison to old technology of FM. (NetProv) The quality was bad at the beginning and as consequence people listened CD or FM (in contrast to marketing slogans): "… it hasn't achieved in showing people that it's something better than normal FM radio." (ModeratorDAB) Sound quality is not necessarily an added valued: : "Because driving in the car, you have so much different noises around you, I think the quality and some distortions in the signal are not that important to most of the listeners" (TransManu)
replacing old technology too expensive	High investment for the new technology both for receiver manufacturer and end user as well as for the transmission systems	Million investments already done for DAB. Concerns since it would require the same for DAB+. (CarManu) Receivers too expensive, not a standard option in new automobiles. (AdvSalesMana) Price for receivers of old FM technology at about 3€ whereas the ones for DAB are at 80€. (EdModContent) People had to pay 50€ for something they already have. (EdMediaMana) Cost of infrastructure expensive. (ContentPlay) Investment is very big for private commercial radios (RadioConsu) Complexity of the infrastructure regarding costs (ChipManu) Too expensive: "I have not the chance for some more money to get the DAB in my car" (ExModMarketer) Infrastructure cost of switching is too high for programmes: "that's our experience of business that the cost to acquire is too high versus the value, too specific but not enough" (IT infrastructure) Difficulty of propagating switch off of the old FM in favour of DAB since individuals had to buy new receiver devices. (TransManu) It takes a lot of R&D effort to develop suitable receivers into new cars (CarManu)
		…

replacing old technology too expensive	High investment for the new technology both for receiver manufacturer and end user as well as for the transmission systems	Million investments already done for DAB. Concerns since it would require the same for DAB+. (CarManu) Receivers too expensive, not a standard option in new automobiles. (AdvSalesMana) Price for receivers of old FM technology at about 3€ whereas the ones for DAB are at 80€. (EdModContent) People had to pay 50€ for something they already have. (EdMediaMana) Cost of infrastructure expensive. (ContentPlay) Investment is very big for private commercial radios (RadioConsu) Complexity of the infrastructure regarding costs (ChipManu) Too expensive: "I have not the chance for some more money to get the DAB in my car" (ExModMarketer) Infrastructure cost of switching is too high for programmes: "that's our experience of business that the cost to acquire is too high versus the value, too specific but not enough" (IT infrastructure) Difficulty of propagating switch off of the old FM in favour of DAB since individuals had to buy new receiver devices. (TransManu) It takes a lot of R&D effort to develop suitable receivers into new cars (CarManu)
Internet as possible technological substitute (possible leap frogging)	internet-based devices hinder people to invest in DAB technology	New technology in sight: people are "looking what the internet offers …" (RadioFut) Youngsters are not as active with radio as up-40s due to their interest in media consumption via internet as YouTube and Facebook (RecManu) There is "a fight between FM and DAB or recently, more latest the fight between IP radio and Digital radio", which represents a leapfrogging situation. (ChipManu) It is a hard time for the listener to decide since "At the moment we force the user of a digital radio to think very hard about how they want to listen, on FM, or DAB or on IP." (ContentPlay) Not in the focus of technology enthusiasts as with other products in consumer electronics: "It's early adopters which are using new technologies and bring these to the mass of the market. (...) just one look to Google, then you will see, it's a 20 years old technology (...) it's the wrong product for people who love trends and to be a techie." (ExModMarketer) substitute technologies are available with smartphones (EdModContent, AdvSalesMana) More innovative technologies are already existing: " If you want to have a digital DAB receiver or a, let's say LTE capable device, which can receive your Spotify or any other music platform content, then at least the young people would rather go for the LTE technology because you have more possibilities with that." (TransManu)
Missing governmental support	switch-over dates pushed the diffusion in other countries, its absence may be important	No clear governmental direction as in other countries (RecManu) No clear governmental push (RecManu) No governmental decision or push unlike in Norway: "Is it important that governments get involved? I think it is important to push ..." (RadioFutur) Lobbyism for other technologies might influence proprietary institutions. (StandForum) Business would hardly accept the new technology without governmental pressure: "... you should have some subventions. (...) Governmental help and governmental pressure to shut down the classical way, because then you have to react, then everybody has to react. " (AdvSalesMana) Missing governmental signals (CarManu)
		…

no green perception	No perception as being more environmentally-friendly, Not referred to as problem for the diffusion of digital radio	Not perceived as green. (AdvSalesMana, EdMediaMana, ContentPlay, RadioConsu) No green perception but people would not care. It's not a buying argument: "This is only nice to have" (NetProv) There are doubts about reduced energy consumption but listeners wouldn't care (StandForum) Without a big meaning: "a), not sure that it is and b), not sure that anyone cares about it." (RadioFutur) Doubts about the perception of listeners to be green. There were some attempts for promoting it but only among broadcasters. (CarManu) Not promoted as green technology (RecManu)
Missing upgradeability	The consumer electronics and car receivers of the broadcasting standard DAB cannot be upgraded to the improved standard of DAB+. Not referred to as problem for the diffusion of digital radio.	The availability of DAB+ as improvement towards DAB was not a big problem: "There are so little users; I don't think that it was a big step into the development of the new technology and the development of DAB. I don't think so. I realise that it is a better quality now in DAB+ because I have a DAB receiver all the time and I now have a DAB+ receiver, but if you look at the selling for the receivers, they are really, really low. They don't sell much of this technology, these receivers, I don't think people even realise there was a switch." (AdvSalesMana) No possibility of updating DAB: "... the kinds of codecs that DAB use have been updated now. We did not build into DAB in our flexibility. You cannot do over the air software updates to put a new codex in to your radio. You are stuck with the original MP2 codex from 1985." (ContentPlay) DAB radios cannot be used for DAB+: "So DAB Plus receivers work on DAB and DAB Plus. The DAB radios will only do DAB, but there's, that's a legacy issue." (RadioConsu) Missing upgradeability from DAB to DAB+ as no big problem, since only a small number had purchased DAB receivers. (EdMediaMana) It was a big discussion when DAB+ was introduced, since all had to be changed due to a lack of compatibility to DAB+ with high costs. / Individuals, who purchase a car, expect to be able to use the receiver technology for 10 years. Unfortunately, DAB receivers are not compatible with DAB+. Now the barely can receive anything. (CarManu) DAB receivers buyer got displeased when DAB+ was introduced due the lack of compatibility. (EdModContent)
Missing upgradeability	The consumer electronics and car receivers of the broadcasting standard DAB cannot be upgraded to the improved standard of DAB+. Not referred to as problem for the diffusion of digital radio.	The availability of DAB+ as improvement towards DAB was not a big problem: "There are so little users; I don't think that it was a big step into the development of the new technology and the development of DAB. I don't think so. I realise that it is a better quality now in DAB+ because I have a DAB receiver all the time and I now have a DAB+ receiver, but if you look at the selling for the receivers, they are really, really low. They don't sell much of this technology, these receivers, I don't think people even realise there was a switch." (AdvSalesMana) No possibility of updating DAB: "... the kinds of codecs that DAB use have been updated now. We did not build into DAB in our flexibility. You cannot do over the air software updates to put a new codex in to your radio. You are stuck with the original MP2 codex from 1985." (ContentPlay) DAB radios cannot be used for DAB+: "So DAB Plus receivers work on DAB and DAB Plus. The DAB radios will only do DAB, but there's, that's a legacy issue." (RadioConsu) Missing upgradeability from DAB to DAB+ as no big problem, since only a small number had purchased DAB receivers. (EdMediaMana) It was a big discussion when DAB+ was introduced, since all had to be changed due to a lack of compatibility to DAB+ with high costs. / Individuals, who purchase a car, expect to be able to use the receiver technology for 10 years. Unfortunately, DAB receivers are not compatible with DAB+. Now the barely can receive anything. (CarManu) DAB receivers buyer got displeased when DAB+ was introduced due the lack of compatibility. (EdModContent)

...

Regional constraints due to political history (difficulty in availability or success)	Regional availability (No national broadcasting allowed in Germany after 2nd World War), Receivers not widely available	In comparison to the UK, where there are only four big commercial radios, Germany's situation is difficult since a lot of private commercial radios need to be on board to push the technology. "In the UK there are now, really only four big commercial radio companies. And I think that makes it easier for us to make strategic decisions about the future of radio in the UK than it is in Germany, where there's a lot me people involved. " (RadioConsu) Governmental constraints in Germany, where no national radio had been allowed so far. (RadioFutur) Before 2011 no nationwide broadcasting: "something totally new for Germany in the radio space because of the way that politics and histories of Germany broadcasting did not provision for a nationwide signal" (ITinfrastructure)
FM technology as global standard	The popularity of the old technology on a global level has a dominant design and is compatible with a lot of electronic products. Therefore hybrid radio is suggested.	The old technology of FM is a well operating global standard of mass media, whereas DAB is regional and therefore it is difficult to be replaced. (EdMediaMana) The FM technology is popular and has achieved a dominant using behaviour: "FM is very popular and the usability of FM is well known. Everybody is aware of the use and FM radio" (ChipManu) The old technology is still very good. (CarManu) DAB-only organizations claim "We need the old technology, if we don't get the old technology the whole radio will fail." (ModeratorDAB) Old technology is still too good and its sound quality is acceptable: "And of course the FM will still be here for many many many years to come". (InfraServiceAUS) The future of radio is a hybrid, intelligent radio using FM, IP and DAB. (ContentPlay) A dominating new technology would not replace old technology, which way there is the need of using existing designs: "... have a look at hybrid radio. The concept of actually from a user's point of view forgetting whether they are tuned in on FM or DAB or the internet, it doesn't actually matter. " (RadioFutur)

Table I-2 – Clustered Summary Table: Digital radio diffusion barriers

Barrier variable	Barrier item	C2 - Missing inter-industrial collaboration	C3 - Lack of marketing	C4 - Missing recognition	C1 - Missing benefit & no added value	C5 - Replacing old technology technology too expensive	C6 - Internet as a technological substitute (possible leapfrogg.)	C7 - Missing governmental support	C8 - No green perception	C9 - Missing upgradeability	C10 - Regional constraints due to political history	C11 - FM technology as global standard
Utility	… is perceived to be less than the older technology				+IC	+IC	/+IC					
	… fails to exceed the older technology's measurable specifications											
Complexity	… focuses attention on overall effectiveness not newest feature				/+IC							
	… renders really new innovation less frequent					/+M						
Complementarity	… of older technology results in higher total utility						/+IC					+IC
	… does no lead to a dominant design											+M
Social context	… creates material limits to access											
	… supports social divisions to access											
	… restricts access on behalf of proprietors / the state							/+M			+M	
Orientations	… towards its use are negative											
	… are towards the older technology											
	-	(+M)						/+M				
Contagion	… is not strong enough to displace existing community norms			+IC								
	… is not dispersed due to poor marketing and/or operations functionality		+M									
Learning capacity	… or cognitive ability limits learning											
	… to access education is limited											
	… of resources / guidance is inadequate											
Learning capability	… generated by older product use does not assist in new technology use											
	… of users has not created a community of expertise											
	… to experience the product is diminished											
Costs of learning	… related to switching are high											
	… of learning determined by the product are prohibitive											

Table I-3 – Mapping table of interview clusters against barrier items of LF-model

Appendix J. Demographic tables of survey analysis

Geographic Region

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Africa	19	2,1	2,1	2,1
	Oceania	28	3,0	3,1	5,1
	Northern America	208	22,6	22,7	27,8
	Asia	237	25,8	25,8	53,7
	Europe	318	34,6	34,7	88,3
	Latin America and the Caribbean	107	11,6	11,7	100,0
	Total	917	99,7	100,0	
Missing	System	3	,3		
Total		920	100,0		

Table J-1 – Frequency of geographic regions as origin of survey respondents

Economic Region

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Developed countries	530	57,6	57,6	57,6
	Emerging countries	321	34,9	34,9	92,5
	Developing countries	69	7,5	7,5	100,0
	Total	920	100,0	100,0	

Table J-2 – Frequency of economic regions as origin of survey respondents

Job position

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Business Development	200	21,7	21,7	21,7
	General Management	78	8,5	8,5	30,2
	Marketing	154	16,7	16,7	47,0
	Product Management	279	30,3	30,3	77,3
	Sales	209	22,7	22,7	100,0
	Total	920	100,0	100,0	

Table J-3 – Frequency of job position of survey respondents

Total number of employees

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	11 – 50	94	10,2	10,2	10,2
	51 – 250	123	13,4	13,4	23,6
	251 – 1000	142	15,4	15,4	39,0
	1,001 - 5,000	127	13,8	13,8	52,8
	5,001 - 10,000	83	9,0	9,0	61,8
	10,001 - 50,000	143	15,5	15,5	77,4
	50,001 - 100,000	89	9,7	9,7	87,1
	more than 100,000	119	12,9	12,9	100,0
	Total	920	100,0	100,0	

Table J-4 – Frequency of company size survey respondents work for

Age

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	younger than 20	1	,1	,1	,1
	20 – 29	51	5,5	5,5	5,7
	30 – 39	365	39,7	39,7	45,3
	40 – 49	343	37,3	37,3	82,6
	50 – 59	143	15,5	15,5	98,2
	60 – 69	17	1,8	1,8	100,0
	Total	920	100,0	100,0	

Table J-5 – Frequency of age groups of survey respondents

Years of experience in current job

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Less than 1 year	25	2,7	2,7	2,7
	1+ years (less than 2 years)	49	5,3	5,3	8,1
	2+ years (less than 4 years)	112	12,2	12,2	20,2
	4+ years (less than 6 years)	103	11,2	11,2	31,4
	6+ years (less than 8 years)	115	12,5	12,5	44,0
	8+ years (less than 10 years)	97	10,5	10,6	54,5
	More than 10 Years	418	45,4	45,5	100,0
	Total	919	99,9	100,0	
Missing	System	1	,1		
Total		920	100,0		

Table J-6 – Frequency of years of experience in current job of survey respondents

Evolutionary sustaining innovation

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Always	164	17,8	17,8	17,8
	Most of the Time	493	53,6	53,6	71,4
	Sometimes	203	22,1	22,1	93,5
	Rarely	55	6,0	6,0	99,5
	Never	5	,5	,5	100,0
	Total	920	100,0	100,0	

Revolutionary sustaining innovation

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Always	42	4,6	4,6	4,6
	Most of the Time	274	29,8	29,8	34,3
	Sometimes	377	41,0	41,0	75,3
	Rarely	188	20,4	20,4	95,8
	Never	39	4,2	4,2	100,0
	Total	920	100,0	100,0	

Disruptive innovation

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Always	83	9,0	9,0	9,0
	Most of the Time	249	27,1	27,1	36,1
	Sometimes	356	38,7	38,7	74,8
	Rarely	203	22,1	22,1	96,8
	Never	29	3,2	3,2	100,0
	Total	920	100,0	100,0	

Table J-7 – Frequencies of different types of innovation the respondents work with

Industrial Good

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Industrial good	613	66,6	67,5	67,5
	Consumer good	295	32,1	32,5	100,0
	Total	908	98,7	100,0	
Missing	System	12	1,3		
Total		920	100,0		

Table J-8 – Frequency of types of good the survey respondents work with

High Technology level

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	High Technology	504	54,8	54,8	54,8
	Medium-High Technology	280	30,4	30,4	85,2
	Medium-Low Technology	106	11,5	11,5	96,7
	Low Technology	30	3,3	3,3	100,0
	Total	920	100,0	100,0	

Table J-9 – Frequency of industry technology-intensitivities of the survey

Industries

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Aeronautics, Defence & Space	46	5,0	5,0	5,0
	Automotive	111	12,1	12,1	17,1
	Chemicals	65	7,1	7,1	24,1
	Computer Hardware/Networking	34	3,7	3,7	27,8
	Consumer Electronics	50	5,4	5,4	33,3
	Consumer Goods	14	1,5	1,5	34,8
	Electrical/Electronic Manufacturing	71	7,7	7,7	42,5
	Food & Beverages	9	1,0	1,0	43,5
	Information Technology & Services	76	8,3	8,3	51,7
	Logistics & Supply Chain	18	2,0	2,0	53,7
	Machinery	15	1,6	1,6	55,3
	Media Production/Distribution	26	2,8	2,8	58,2
	Medical industries	117	12,7	12,7	70,9
	Oil & Energy	74	8,0	8,0	78,9
	Pharmaceuticals & Biotech	55	6,0	6,0	84,9
	Renewables & Environment	17	1,8	1,8	86,7
	Telecommunication	100	10,9	10,9	97,6
	Construction	13	1,4	1,4	99,0
	Mining, metals and minerals	1	,1	,1	99,1
	Maritime industries	1	,1	,1	99,2
	Textiles and clothing	5	,5	,5	99,8
	Wood, Paper & Printing	2	,2	,2	100,0
	Total	920	100,0	100,0	

Table J-10 – Frequency of industries the survey respondents work in

Industries * Industrial Good Crosstabulation

			Industrial Good		Total
			Industrial good	Consumer good	
Industries	Aeronautics, Defence & Space	Count	42	4	46
		% within Industries	91,3%	8,7%	100,0%
	Automotive	Count	65	44	109
		% within Industries	59,6%	40,4%	100,0%
	Chemicals	Count	58	5	63
		% within Industries	92,1%	7,9%	100,0%
	Computer Hardware/Networking	Count	20	14	34
		% within Industries	58,8%	41,2%	100,0%
	Consumer Electronics	Count	5	45	50
		% within Industries	10,0%	90,0%	100,0%
	Electrical/Electronic Manufacturing	Count	55	16	71
		% within Industries	77,5%	22,5%	100,0%
	Information Technology & Services	Count	58	17	75
		% within Industries	77,3%	22,7%	100,0%
	Logistics & Supply Chain	Count	11	7	18
		% within Industries	61,1%	38,9%	100,0%
	Machinery	Count	14	0	14
		% within Industries	100,0%	0,0%	100,0%
	Media Production/Distribution	Count	16	10	26
		% within Industries	61,5%	38,5%	100,0%
	Medical industries	Count	66	50	116
		% within Industries	56,9%	43,1%	100,0%
	Pharmaceuticals & Biotech	Count	26	29	55
		% within Industries	47,3%	52,7%	100,0%
	Telecommunication	Count	71	27	98
		% within Industries	72,4%	27,6%	100,0%
Total		Count	507	268	775
		% within Industries	65,4%	34,6%	100,0%

Table J-11 – Cross-tabulation of types of good and industries of the survey

Appendix K. Central tendencies of survey analysis

Statistics of Likert-type items for barriers perceived by experts from manufacturing industries

	N		Mean	Median	Mode	Skewness
	valid	m				
Utility perceived to be less than o.T.	920	0	4,38	5,00	6	-,361
n.T. fails to exceed measurable specifications of o.T.	920	0	4,21	4,00	6	-,162
Complexity focuses attention on overall effectiveness	920	0	3,70	3,00	3	,305
Complex radically n.T. cannot be introduced frequently	920	0	2,95	3,00	2	,811
Complementarity of o.T. results in higher total utility	920	0	3,39	3,00	3	,507
No dominant design within an industry compared to o.T.	920	0	3,41	3,00	3	,486
Not adaptable and not perceived to be future-ready	920	0	3,95	4,00	3	,042
n.T. not adaptable to community needs	920	0	4,39	5,00	6	-,223
Cannot be adapted to other industries	920	0	4,08	4,00	3	-,020
Individuals face difficulties in accessing n.T.	920	0	3,69	3,00	3	,239
Access is granted to small social groups	920	0	3,77	4,00	3	,232
Access is restricted by external institutions (e.g. government)	920	0	4,40	4,00	6	-,282
Personal orientations towards its use are negative.	920	0	4,33	4,00	6	-,154
Community of users is towards o.T.	920	0	3,67	3,00	3	,380
Community discussions about an even better T.	920	0	3,70	4,00	4	,281
Missing industry collaboration	920	0	4,10	4,00	3	-,055
Contagion not strong enough to displace community norms.	920	0	3,63	3,00	3	,346
Poor execution of marketing	920	0	3,17	3,00	2	,619
Not perceived as more environmentally friendly than o.T.	920	0	4,38	4,00	4	-,064
Sustainability aspects of n.T. not explained to community	920	0	3,80	3,00	3	,198
Marketing exaggerates environmentally friendliness	920	0	3,54	3,00	3	,300
Limited individual learning capacity or ability	920	0	4,19	4,00	3	-,071
Not enough resource to access training	920	0	3,63	3,00	3	,364
Not sufficient resources & guidance for learning n.T.	920	0	3,76	3,00	3	,196
Way of using very different compared to o.T.	920	0	3,85	4,00	3	,096
No community expert group created for n.T.	920	0	3,97	4,00	3	,096
No possibilities for experiencing n.T. in industry	920	0	3,60	3,00	3	,423
High switching costs and learning efforts	920	0	2,92	3,00	2	,772
Learning efforts within industry are expensive.	920	0	3,68	3,00	3	,205

Table K-1 – Tendencies of barrier items in manufacturing industries

Statistics of Likert-type items for barriers perceived by experts in technology-intensive industries

	N valid	N m	Mean	Median	Mode	Skewness
Utility perceived to be less than o.T.	726	0	4,40	5,00	6	-,390
n.T. fails to exceed measurable specifications of o.T.	726	0	4,21	4,00	6	-,159
Complexity focuses attention on overall effectiveness	726	0	3,72	3,00	3	,288
Complex radically n.T. cannot be introduced frequently	726	0	2,97	3,00	2	,789
Complementarity of o.T. results in higher total utility	726	0	3,41	3,00	3	,500
No dominant design within an industry compared to o.T.	726	0	3,45	3,00	3	,487
Not adaptable and not perceived to be future-ready	726	0	3,98	4,00	3	,013
n.T. not adaptable to community needs	726	0	4,39	5,00	6	-,223
Cannot be adapted to other industries	726	0	4,08	4,00	3	-,004
Individuals face difficulties in accessing n.T.	726	0	3,71	3,00	3	,225
Access is granted to small social groups	726	0	3,80	4,00	3	,270
Access is restricted by external institutions (e.g. government)	726	0	4,40	4,00	6	-,287
Personal orientations towards its use are negative.	726	0	4,39	4,00	6	-,215
Community of users is towards o.T.	726	0	3,75	3,00	3	,358
Community discussions about an even better technology	726	0	3,64	4,00	3	,274
Missing industry collaboration	726	0	4,07	4,00	3	-,046
Contagion not strong enough to displace community norms.	726	0	3,69	3,00	3	,351
Poor execution of marketing	726	0	3,19	3,00	2	,617
Not perceived as more environmentally friendly than o.T.	726	0	4,35	4,00	4	-,076
Sustainability aspects of n.T. not explained to community	726	0	3,79	3,00	3	,199
Marketing exaggerates environmentally friendliness	726	0	3,50	3,00	3	,297
Limited individual learning capacity or ability	726	0	4,24	4,00	3[a]	-,114
Not enough resource to access training	726	0	3,65	3,00	3	,357
Not sufficient resources & guidance for learning n.T.	726	0	3,75	3,00	3	,226
Way of using very different compared to o.T.	726	0	3,93	4,00	3	,076
No community expert group created for n.T.	726	0	3,99	4,00	3	,086
No possibilities for experiencing n.T. in industry	726	0	3,67	3,00	3	,411
High switching costs and learning efforts	726	0	3,01	3,00	3	,692
Learning efforts within industry are expensive.	726	0	3,67	3,00	3	,205

Table K-2 – Tendencies of barrier items in technology-intensive industries

Statistics of Likert-type scales for barriers perceived by experts in technology-intensive industries

	N		Mean	Median	Mode	Std. Deviation
	Valid	Missing				
Technology - Utility	726	0	4,3017	4,5000	4,00	1,37487
Technology - Complexity	726	0	3,3464	3,0000	2,50	1,24020
Technology - Complementarity	726	0	3,4311	3,5000	3,00	1,14594
Technology - Adaptability	726	0	4,1492	4,0000	3,33	1,16260
Social Structure – Social context	726	0	3,9715	4,0000	3,67	1,19608
Social Structure - Orientations	726	0	4,0716	4,0000	4,00	1,11778
Social Structure - Contagion	726	0	3,4408	3,5000	4,00	1,14015
Social Structure - Environmental Awareness	726	0	3,8797	4,0000	4,00	1,06043
Learning – Learning capacity	726	0	3,8797	3,6667	3,67	1,18286
Learning – Learning capability	726	0	3,8641	3,6667	3,33[a]	1,13646
Learning – Costs of learning	726	0	3,3395	3,0000	3,00	1,30836

a. Multiple modes exist. The smallest value is shown

Table K-3 – Tendencies of barrier variables of technology-intensive industries

Statistics of Likert-type items for barriers perceived by Aeronautics, Defence & Space experts

	N		Mean	Median	Mode	Skewness
	Valid	M				
Utility perceived to be less than o.T.	46	0	4,54	5,00	5	-,864
n.T. fails to exceed measurable specifications of o.T.	46	0	4,33	4,50	3	-,198
Complexity focuses attention on overall effectiveness	46	0	3,87	3,00	3	,225
Complex radically n.T. cannot be introduced frequently	46	0	2,74	3,00	2	1,428
Complementarity of o.T. results in higher total utility	46	0	3,33	3,00	3	,427
No dominant design within an industry compared to o.T.	46	0	3,04	3,00	3	1,035
Not adaptable and not perceived to be future-ready	46	0	4,30	5,00	6	-,507
n.T. not adaptable to community needs	46	0	4,33	4,00	4	-,225
Cannot be adapted to other industries	46	0	3,80	4,00	4	,168
Individuals face difficulties in accessing n.T.	46	0	3,96	4,00	3	,079
Access is granted to small social groups	46	0	3,83	4,00	4	,055
Access is restricted by external institutions (e.g. government)	46	0	3,98	4,00	6	-,097
Personal orientations towards its use are negative.	46	0	4,37	4,00	6	-,247
Community of users is towards o.T.	46	0	3,59	3,00	3	,309
Missing industry collaboration	46	0	3,76	4,00	3[a]	-,089
Contagion not strong enough to displace community norms.	46	0	3,63	3,50	3	,526
Poor execution of marketing	46	0	3,13	3,00	2	,419
Not perceived as more environmentally friendly than o.T.	46	0	4,59	4,00	4	,086
Sustainability aspects of n.T. not explained to community	46	0	3,63	3,00	2	,317
Marketing exaggerates environmentally friendliness	46	0	3,59	4,00	4	-,030
Limited individual learning capacity or ability	46	0	4,20	4,00	3	-,120
Not enough resource to access training	46	0	3,93	4,00	3[a]	-,191
Not sufficient resources & guidance for learning n.T.	46	0	3,59	3,00	3	,251
Way of using very different compared to o.T.	46	0	3,72	3,00	3	,302
No community expert group created for n.T.	46	0	4,11	4,00	3	,163
No possibilities for experiencing n.T. in industry	46	0	3,65	3,00	3	,120
High switching costs and learning efforts	46	0	2,63	2,00	2[a]	1,164
Learning efforts within industry are expensive.	46	0	3,37	3,00	3	,131

Table K-4 – Tendencies of barrier items in aeronautics, defence & space

Statistics of Likert-type items for barriers perceived by automotive experts

	N		Mean	Median	Mode	Skewness
	Valid	M				
Utility perceived to be less than o.T.	111	0	4,37	5,00	6	-,437
n.T. fails to exceed measurable specifications of o.T.	111	0	4,19	4,00	6	,016
Complexity focuses attention on overall effectiveness	111	0	3,60	3,00	3[a]	,115
Complex radically n.T. cannot be introduced frequently	111	0	2,86	2,00	2	,804
Complementarity of o.T. results in higher total utility	111	0	3,33	3,00	3	,381
No dominant design within an industry compared to o.T.	111	0	3,25	3,00	2	,573
Not adaptable and not perceived to be future-ready	111	0	3,83	4,00	3	,024
n.T. not adaptable to community needs	111	0	4,32	4,00	3	-,105
Cannot be adapted to other industries	111	0	4,02	4,00	3	,069
Individuals face difficulties in accessing n.T.	111	0	3,51	3,00	3	,284
Access is granted to small social groups	111	0	3,61	3,00	3	,335
Access is restricted by external institutions (e.g. government)	111	0	4,49	5,00	6	-,281
Personal orientations towards its use are negative.	111	0	4,31	4,00	4	-,065
Community of users is towards o.T.	111	0	3,77	3,00	2	,335
Missing industry collaboration	111	0	4,13	4,00	3	-,019
Contagion not strong enough to displace community norms.	111	0	3,60	3,00	3	,459
Poor execution of marketing	111	0	3,31	3,00	3	,520
Not perceived as more environmentally friendly than o.T.	111	0	4,34	4,00	4	-,043
Sustainability aspects of n.T. not explained to community	111	0	3,85	3,00	3	,238
Marketing exaggerates environmentally friendliness	111	0	3,35	3,00	3	,211
Limited individual learning capacity or ability	111	0	4,14	4,00	6	-,156
Not enough resource to access training	111	0	3,60	3,00	3	,459
Not sufficient resources & guidance for learning n.T.	111	0	4,00	4,00	3	,170
Way of using very different compared to o.T.	111	0	3,99	4,00	6	-,145
No community expert group created for n.T.	111	0	3,80	4,00	3	,213
No possibilities for experiencing n.T. in industry	111	0	3,45	3,00	3	,584
High switching costs and learning efforts	111	0	2,92	3,00	2	,593
Learning efforts within industry are expensive.	111	0	3,65	3,00	3	,065

Table K-5 – Tendencies of barrier items in automotive

Statistics of Likert-type items for barriers perceived by automotive experts for industrial goods

	N		Mean	Median	Mode	Skewness
	Valid	M				
Utility perceived to be less than o.T.	65	0	4,34	5,00	6	-,539
n.T. fails to exceed measurable specifications of o.T.	65	0	4,12	4,00	3[a]	,235
Complexity focuses attention on overall effectiveness	65	0	3,86	4,00	5	-,225
Complex radically n.T. cannot be introduced frequently	65	0	2,91	2,00	2	,796
Complementarity of o.T. results in higher total utility	65	0	3,45	3,00	3	,245
No dominant design within an industry compared to o.T.	65	0	3,31	3,00	2	,492
Not adaptable and not perceived to be future-ready	65	0	4,00	4,00	3[a]	,000
n.T. not adaptable to community needs	65	0	4,43	5,00	3	-,129
Cannot be adapted to other industries	65	0	4,11	4,00	3	,025
Individuals face difficulties in accessing n.T.	65	0	3,58	3,00	3	,161
Access is granted to small social groups	65	0	3,85	4,00	3	,182
Access is restricted by external institutions (e.g. government)	65	0	4,43	5,00	6	-,300
Personal orientations towards its use are negative.	65	0	4,32	4,00	4[a]	,038
Community of users is towards o.T.	65	0	3,72	3,00	3	,189
Missing industry collaboration	65	0	4,18	4,00	3[a]	-,028
Contagion not strong enough to displace community norms.	65	0	3,77	4,00	3	,317
Poor execution of marketing	65	0	3,34	3,00	3	,669
Not perceived as more environmentally friendly than o.T.	65	0	4,46	4,00	4	,002
Sustainability aspects of n.T. not explained to community	65	0	3,88	4,00	3	,057
Marketing exaggerates environmentally friendliness	65	0	3,46	3,00	3	,130
Limited individual learning capacity or ability	65	0	4,14	4,00	3	-,066
Not enough resource to access training	65	0	3,62	3,00	3	,585
Not sufficient resources & guidance for learning n.T.	65	0	3,97	4,00	3	,052
Way of using very different compared to o.T.	65	0	4,12	4,00	6	-,257
No community expert group created for n.T.	65	0	3,94	4,00	5	-,082
No possibilities for experiencing n.T. in industry	65	0	3,45	3,00	3	,451
High switching costs and learning efforts	65	0	3,08	3,00	2	,516
Learning efforts within industry are expensive.	65	0	3,86	4,00	3	,123

Table K-6 – Tendencies of barrier items in automotive (B2B)

Statistics of Likert-type items for barriers perceived by automotive experts for consumer goods

	N		Mean	Median	Mode	Skewness
	Valid	M				
Utility perceived to be less than o.T.	44	0	4,43	5,00	5	-,287
n.T. fails to exceed measurable specifications of o.T.	44	0	4,23	4,50	6	-,194
Complexity focuses attention on overall effectiveness	44	0	3,30	3,00	2	,556
Complex radically n.T. cannot be introduced frequently	44	0	2,75	2,50	2	,861
Complementarity of o.T. results in higher total utility	44	0	3,18	3,00	3	,604
No dominant design within an industry compared to o.T.	44	0	3,20	3,00	2	,664
Not adaptable and not perceived to be future-ready	44	0	3,64	3,50	3	-,072
n.T. not adaptable to community needs	44	0	4,18	4,00	3	,008
Cannot be adapted to other industries	44	0	3,91	4,00	2	,118
Individuals face difficulties in accessing n.T.	44	0	3,39	3,00	3	,470
Access is granted to small social groups	44	0	3,27	3,00	3	,656
Access is restricted by external institutions (e.g. government)	44	0	4,55	5,00	3	-,207
Personal orientations towards its use are negative.	44	0	4,30	4,50	5	-,195
Community of users is towards o.T.	44	0	3,86	3,50	2	,487
Missing industry collaboration	44	0	4,07	4,00	3	-,047
Contagion not strong enough to displace community norms.	44	0	3,39	3,00	3	,565
Poor execution of marketing	44	0	3,30	3,00	2[a]	,336
Not perceived as more environmentally friendly than o.T.	44	0	4,20	4,00	4	-,057
Sustainability aspects of n.T. not explained to community	44	0	3,82	3,00	3	,508
Marketing exaggerates environmentally friendliness	44	0	3,16	3,00	2	,400
Limited individual learning capacity or ability	44	0	4,07	4,00	5	-,251
Not enough resource to access training	44	0	3,59	3,00	3	,344
Not sufficient resources & guidance for learning n.T.	44	0	4,07	4,00	3	,344
Way of using very different compared to o.T.	44	0	3,82	3,00	3	,001
No community expert group created for n.T.	44	0	3,66	3,00	3	,608
No possibilities for experiencing n.T. in industry	44	0	3,45	3,00	2[a]	,794
High switching costs and learning efforts	44	0	2,70	2,50	2	,569
Learning efforts within industry are expensive.	44	0	3,32	3,00	2	,132

Table K-7 – Tendencies of barrier items in automotive (B2C)

Statistics of Likert-type items for barriers perceived by chemicals industry experts

	N		Mean	Median	Mode	Skewness
	Valid	M				
Utility perceived to be less than o.T.	65	0	4,34	5,00	5	-,103
n.T. fails to exceed measurable specifications of o.T.	65	0	4,08	4,00	3[a]	-,216
Complexity focuses attention on overall effectiveness	65	0	3,78	3,00	3	,415
Complex radically n.T. cannot be introduced frequently	65	0	2,75	2,00	2	1,253
Complementarity of o.T. results in higher total utility	65	0	3,46	3,00	3	,127
No dominant design within an industry compared to o.T.	65	0	3,14	3,00	3	,759
Not adaptable and not perceived to be future-ready	65	0	3,83	4,00	5	-,067
n.T. not adaptable to community needs	65	0	4,52	5,00	6	-,459
Cannot be adapted to other industries	65	0	4,14	4,00	4	,074
Individuals face difficulties in accessing n.T.	65	0	3,94	4,00	4	-,126
Access is granted to small social groups	65	0	3,82	4,00	3	,357
Access is restricted by external institutions (e.g. government)	65	0	4,43	5,00	6	-,481
Personal orientations towards its use are negative.	65	0	4,58	5,00	5[a]	-,243
Community of users is towards o.T.	65	0	3,54	3,00	3	,583
Missing industry collaboration	65	0	4,14	5,00	6	-,217
Contagion not strong enough to displace community norms.	65	0	3,65	3,00	3	,169
Poor execution of marketing	65	0	3,09	3,00	2	,808
Not perceived as more environmentally friendly than o.T.	65	0	4,58	5,00	6	-,489
Sustainability aspects of n.T. not explained to community	65	0	4,00	3,00	3	,180
Marketing exaggerates environmentally friendliness	65	0	3,40	3,00	3	,311
Limited individual learning capacity or ability	65	0	4,34	4,00	6	-,084
Not enough resource to access training	65	0	3,68	3,00	3	,223
Not sufficient resources & guidance for learning n.T.	65	0	3,68	3,00	3	,129
Way of using very different compared to o.T.	65	0	4,18	4,00	6	-,167
No community expert group created for n.T.	65	0	4,06	4,00	2[a]	,147
No possibilities for experiencing n.T. in industry	65	0	3,43	3,00	3	,669
High switching costs and learning efforts	65	0	2,94	3,00	3	,874
Learning efforts within industry are expensive.	65	0	3,78	3,00	3	,210

Table K-8 – Tendencies of barrier items in chemicals

Statistics of Likert-type items for barriers perceived by consumer electronics industry experts

	N		Mean	Median	Mode	Skewness
	Valid	M				
Utility perceived to be less than o.T.	50	0	4,46	5,00	5[a]	-,214
n.T. fails to exceed measurable specifications of o.T.	50	0	4,04	4,00	3	,023
Complexity focuses attention on overall effectiveness	50	0	3,64	3,00	2	,413
Complex radically n.T. cannot be introduced frequently	50	0	3,24	3,00	2	,581
Complementarity of o.T. results in higher total utility	50	0	3,18	3,00	3	,631
No dominant design within an industry compared to o.T.	50	0	4,02	4,00	3	,365
Not adaptable and not perceived to be future-ready	50	0	4,02	4,00	3	,249
n.T. not adaptable to community needs	50	0	4,28	4,00	4	,093
Cannot be adapted to other industries	50	0	4,46	5,00	5	-,319
Individuals face difficulties in accessing n.T.	50	0	3,62	3,00	2	,456
Access is granted to small social groups	50	0	3,66	3,00	3	,184
Access is restricted by external institutions (e.g. government)	50	0	4,58	5,00	6	-,420
Personal orientations towards its use are negative.	50	0	4,32	4,00	4	-,205
Community of users is towards o.T.	50	0	4,16	4,00	3	,256
Missing industry collaboration	50	0	4,00	4,00	3	-,239
Contagion not strong enough to displace community norms.	50	0	4,18	4,00	3	,006
Poor execution of marketing	50	0	3,00	3,00	2	,546
Not perceived as more environmentally friendly than o.T.	50	0	4,08	4,00	4	,201
Sustainability aspects of n.T. not explained to community	50	0	3,78	3,50	3	,159
Marketing exaggerates environmentally friendliness	50	0	3,36	3,00	3	,420
Limited individual learning capacity or ability	50	0	4,02	4,00	3	,240
Not enough resource to access training	50	0	3,64	3,00	3	,566
Not sufficient resources & guidance for learning n.T.	50	0	3,64	3,00	3	,528
Way of using very different compared to o.T.	50	0	4,00	4,00	4	-,037
No community expert group created for n.T.	50	0	4,28	5,00	6	-,271
No possibilities for experiencing n.T. in industry	50	0	3,74	3,00	3	,479
High switching costs and learning efforts	50	0	3,64	3,00	3	,411
Learning efforts within industry are expensive.	50	0	3,88	4,00	2	,007

Table K-9 – Tendencies of barrier items in consumer electronics

Statistics of Likert-type items for barriers perceived by electric/electronic manufacturing experts

	N		Mean	Median	Mode	Skewness
	Valid	M				
Utility perceived to be less than o.T.	71	0	4,58	5,00	6	-,436
n.T. fails to exceed measurable specifications of o.T.	71	0	4,45	5,00	6	-,475
Complexity focuses attention on overall effectiveness	71	0	3,92	4,00	3	,156
Complex radically n.T. cannot be introduced frequently	71	0	3,03	3,00	2	,854
Complementarity of o.T. results in higher total utility	71	0	3,48	3,00	3	,279
No dominant design within an industry compared to o.T.	71	0	3,58	3,00	2	,265
Not adaptable and not perceived to be future-ready	71	0	4,03	4,00	3	,086
n.T. not adaptable to community needs	71	0	4,54	5,00	5[a]	-,337
Cannot be adapted to other industries	71	0	4,23	4,00	6	-,111
Individuals face difficulties in accessing n.T.	71	0	3,99	4,00	3	-,271
Access is granted to small social groups	71	0	4,20	4,00	3	,120
Access is restricted by external institutions (e.g. government)	71	0	4,75	5,00	6	-,429
Personal orientations towards its use are negative.	71	0	4,51	5,00	5	-,369
Community of users is towards o.T.	71	0	3,44	3,00	3	,654
Missing industry collaboration	71	0	4,23	4,00	6	-,111
Contagion not strong enough to displace community norms.	71	0	3,68	3,00	2	,162
Poor execution of marketing	71	0	3,44	3,00	3	,307
Not perceived as more environmentally friendly than o.T.	71	0	4,37	4,00	6	-,169
Sustainability aspects of n.T. not explained to community	71	0	3,92	3,00	3	,162
Marketing exaggerates environmentally friendliness	71	0	3,59	3,00	3	,357
Limited individual learning capacity or ability	71	0	4,24	4,00	3	-,016
Not enough resource to access training	71	0	3,68	3,00	3	,280
Not sufficient resources & guidance for learning n.T.	71	0	3,63	3,00	2	,175
Way of using very different compared to o.T.	71	0	3,99	4,00	2	,293
No community expert group created for n.T.	71	0	4,04	4,00	3	,109
No possibilities for experiencing n.T. in industry	71	0	3,69	3,00	3	,368
High switching costs and learning efforts	71	0	3,08	3,00	3	,328
Learning efforts within industry are expensive.	71	0	3,93	4,00	3	,075

Table K-10 – Tendencies of barrier items in electr. /electronic manufacturing

Statistics of Likert-type items for barriers perceived by information technology industry experts

	N		Mean	Median	Mode	Skewness
	Valid	M				
Utility perceived to be less than o.T.	76	0	5,01	5,00	6	-,919
n.T. fails to exceed measurable specifications of o.T.	76	0	4,37	4,50	6	-,315
Complexity focuses attention on overall effectiveness	76	0	3,97	4,00	3	,109
Complex radically n.T. cannot be introduced frequently	76	0	3,00	3,00	2	,629
Complementarity of o.T. results in higher total utility	76	0	3,63	4,00	3	,154
No dominant design within an industry compared to o.T.	76	0	3,46	3,00	2	,347
Not adaptable and not perceived to be future-ready	76	0	4,39	5,00	5[a]	-,248
n.T. not adaptable to community needs	76	0	4,72	5,00	6	-,420
Cannot be adapted to other industries	76	0	4,66	5,00	6	-,489
Individuals face difficulties in accessing n.T.	76	0	4,05	4,00	6	-,019
Access is granted to small social groups	76	0	3,93	4,00	3	,110
Access is restricted by external institutions (e.g. government)	76	0	4,71	5,00	6	-,391
Personal orientations towards its use are negative.	76	0	4,37	4,00	6	-,102
Community of users is towards o.T.	76	0	4,14	4,00	3	,062
Missing industry collaboration	76	0	4,01	4,00	3	,144
Contagion not strong enough to displace community norms.	76	0	3,67	3,00	3	,373
Poor execution of marketing	76	0	3,20	3,00	2	,694
Not perceived as more environmentally friendly than o.T.	76	0	4,57	4,00	4	-,205
Sustainability aspects of n.T. not explained to community	76	0	3,63	3,00	2[a]	,118
Marketing exaggerates environmentally friendliness	76	0	3,50	3,50	4	,288
Limited individual learning capacity or ability	76	0	4,37	4,00	6	-,207
Not enough resource to access training	76	0	3,70	3,00	3	,257
Not sufficient resources & guidance for learning n.T.	76	0	3,61	3,00	3	,266
Way of using very different compared to o.T.	76	0	4,07	4,00	3	,072
No community expert group created for n.T.	76	0	3,75	3,00	2	,180
No possibilities for experiencing n.T. in industry	76	0	3,89	4,00	3	,184
High switching costs and learning efforts	76	0	3,09	3,00	3	,803
Learning efforts within industry are expensive.	76	0	3,93	4,00	3	,068

Table K-11 – Tendencies of barrier items in IT industry

Statistics of Likert-type items for barriers perceived by medical industry experts

	N		Mean	Median	Mode	Skewness
	Valid	M				
Utility perceived to be less than o.T.	117	0	4,23	5,00	6	-,304
n.T. fails to exceed measurable specifications of o.T.	117	0	4,21	4,00	6	-,162
Complexity focuses attention on overall effectiveness	117	0	3,74	3,00	3	,463
Complex radically n.T. cannot be introduced frequently	117	0	2,99	2,00	2	,874
Complementarity of o.T. results in higher total utility	117	0	3,58	3,00	3	,589
No dominant design within an industry compared to o.T.	117	0	3,56	3,00	3	,538
Not adaptable and not perceived to be future-ready	117	0	4,11	4,00	2[a]	,098
n.T. not adaptable to community needs	117	0	4,31	4,00	3	-,037
Cannot be adapted to other industries	117	0	3,79	3,00	3	,130
Individuals face difficulties in accessing n.T.	117	0	3,64	3,00	3	,398
Access is granted to small social groups	117	0	3,64	3,00	3	,524
Access is restricted by external institutions (e.g. government)	117	0	3,97	4,00	3	,030
Personal orientations towards its use are negative.	117	0	4,54	5,00	6	-,170
Community of users is towards o.T.	117	0	3,67	3,00	3	,505
Missing industry collaboration	117	0	4,13	4,00	3	,006
Contagion not strong enough to displace community norms.	117	0	3,72	3,00	3	,577
Poor execution of marketing	117	0	3,19	3,00	2[a]	,716
Not perceived as more environmentally friendly than o.T.	117	0	4,40	4,00	4	,049
Sustainability aspects of n.T. not explained to community	117	0	3,62	3,00	2	,337
Marketing exaggerates environmentally friendliness	117	0	3,69	4,00	4	,120
Limited individual learning capacity or ability	117	0	4,39	5,00	6	-,129
Not enough resource to access training	117	0	3,65	3,00	3	,463
Not sufficient resources & guidance for learning n.T.	117	0	3,80	3,00	3	,264
Way of using very different compared to o.T.	117	0	3,86	3,00	3	,224
No community expert group created for n.T.	117	0	4,01	4,00	6	,016
No possibilities for experiencing n.T. in industry	117	0	3,93	3,00	3	,205
High switching costs and learning efforts	117	0	3,03	3,00	2	,619
Learning efforts within industry are expensive.	117	0	3,44	3,00	3	,520

Table K-12 – Tendencies of barrier items in medical industry

Statistics of Likert-type items for barriers perceived by medical experts for industrial goods

	N		Mean	Median	Mode	Skewness
	Valid	M				
Utility perceived to be less than o.T.	66	0	4,11	4,00	6	-,164
n.T. fails to exceed measurable specifications of o.T.	66	0	4,20	4,00	6	-,223
Complexity focuses attention on overall effectiveness	66	0	3,77	3,00	2	,328
Complex radically n.T. cannot be introduced frequently	66	0	3,05	2,00	2	,856
Complementarity of o.T. results in higher total utility	66	0	3,62	3,00	3	,476
No dominant design within an industry compared to o.T.	66	0	3,67	3,00	3	,428
Not adaptable and not perceived to be future-ready	66	0	4,12	4,00	4	,120
n.T. not adaptable to community needs	66	0	4,33	4,00	3	,156
Cannot be adapted to other industries	66	0	3,97	4,00	3	,118
Individuals face difficulties in accessing n.T.	66	0	3,74	3,00	2[a]	,302
Access is granted to small social groups	66	0	3,70	3,00	3	,518
Access is restricted by external institutions (e.g. government)	66	0	4,06	4,00	6	-,107
Personal orientations towards its use are negative.	66	0	4,47	4,00	6	-,099
Community of users is towards o.T.	66	0	3,56	3,00	3	,448
Missing industry collaboration	66	0	4,14	4,00	6	-,115
Contagion not strong enough to displace community norms.	66	0	3,76	3,00	3	,556
Poor execution of marketing	66	0	2,91	3,00	2	1,046
Not perceived as more environmentally friendly than o.T.	66	0	4,48	4,00	4[a]	-,105
Sustainability aspects of n.T. not explained to community	66	0	3,73	4,00	3[a]	,297
Marketing exaggerates environmentally friendliness	66	0	3,67	4,00	4	,038
Limited individual learning capacity or ability	66	0	4,36	5,00	6	-,153
Not enough resource to access training	66	0	3,86	3,00	3	,393
Not sufficient resources & guidance for learning n.T.	66	0	3,80	3,00	3	,148
Way of using very different compared to o.T.	66	0	3,89	3,00	6	,095
No community expert group created for n.T.	66	0	4,06	3,50	3	,117
No possibilities for experiencing n.T. in industry	66	0	3,97	3,00	3	,308
High switching costs and learning efforts	66	0	2,98	3,00	2	,496
Learning efforts within industry are expensive.	66	0	3,39	3,00	3	,564

Table K-13 – Tendencies of barrier items in medical industry (B2B)

Statistics of Likert-type items for barriers perceived by medical experts for consumer goods

	N		Mean	Median	Mode	Skewness
	Valid	M				
Utility perceived to be less than o.T.	50	0	4,36	5,00	6	-,465
n.T. fails to exceed measurable specifications of o.T.	50	0	4,26	5,00	5	-,106
Complexity focuses attention on overall effectiveness	50	0	3,66	3,00	3	,743
Complex radically n.T. cannot be introduced frequently	50	0	2,94	3,00	2	,900
Complementarity of o.T. results in higher total utility	50	0	3,56	3,00	3	,685
No dominant design within an industry compared to o.T.	50	0	3,44	3,00	3	,685
Not adaptable and not perceived to be future-ready	50	0	4,06	4,00	2	,131
n.T. not adaptable to community needs	50	0	4,24	4,00	6	-,182
Cannot be adapted to other industries	50	0	3,60	3,00	3	,171
Individuals face difficulties in accessing n.T.	50	0	3,54	3,00	3	,501
Access is granted to small social groups	50	0	3,54	3,00	3	,571
Access is restricted by external institutions (e.g. government)	50	0	3,84	3,00	3	,246
Personal orientations towards its use are negative.	50	0	4,60	5,00	5[a]	-,224
Community of users is towards o.T.	50	0	3,84	3,00	3	,502
Missing industry collaboration	50	0	4,08	3,50	3	,194
Contagion not strong enough to displace community norms.	50	0	3,68	3,00	3	,597
Poor execution of marketing	50	0	3,52	3,00	3	,389
Not perceived as more environmentally friendly than o.T.	50	0	4,26	4,00	4	,294
Sustainability aspects of n.T. not explained to community	50	0	3,42	3,00	2	,491
Marketing exaggerates environmentally friendliness	50	0	3,70	4,00	4	,211
Limited individual learning capacity or ability	50	0	4,40	4,50	3[a]	-,067
Not enough resource to access training	50	0	3,38	3,00	3	,583
Not sufficient resources & guidance for learning n.T.	50	0	3,76	3,00	3	,427
Way of using very different compared to o.T.	50	0	3,78	3,00	3	,446
No community expert group created for n.T.	50	0	3,90	4,00	2[a]	-,078
No possibilities for experiencing n.T. in industry	50	0	3,84	4,00	3	,158
High switching costs and learning efforts	50	0	3,08	3,00	2	,762
Learning efforts within industry are expensive.	50	0	3,46	3,00	2	,523

Table K-14 – Tendencies of barrier items in medical industry (B2C)

Statistics of Likert-type items for barriers perceived by pharmaceutical and biotechnology experts

	N		Mean	Median	Mode	Skewness
	Valid	M				
Utility perceived to be less than o.T.	55	0	3,96	4,00	6	-,050
n.T. fails to exceed measurable specifications of o.T.	55	0	3,91	4,00	6	-,065
Complexity focuses attention on overall effectiveness	55	0	3,35	3,00	2[a]	,702
Complex radically n.T. cannot be introduced frequently	55	0	3,00	2,00	2	,712
Complementarity of o.T. results in higher total utility	55	0	3,27	3,00	2	,717
No dominant design within an industry compared to o.T.	55	0	3,24	3,00	2	,626
Not adaptable and not perceived to be future-ready	55	0	3,58	3,00	2[a]	,424
n.T. not adaptable to community needs	55	0	3,87	4,00	2[a]	-,081
Cannot be adapted to other industries	55	0	3,75	4,00	3	,098
Individuals face difficulties in accessing n.T.	55	0	3,05	3,00	3	,969
Access is granted to small social groups	55	0	3,29	3,00	2	,575
Access is restricted by external institutions (e.g. government)	55	0	3,75	4,00	4	,021
Personal orientations towards its use are negative.	55	0	3,71	4,00	3	,214
Community of users is towards o.T.	55	0	3,18	3,00	3	,640
Missing industry collaboration	55	0	3,85	4,00	4	-,067
Contagion not strong enough to displace community norms.	55	0	3,09	3,00	3	,431
Poor execution of marketing	55	0	3,02	3,00	2	,711
Not perceived as more environmentally friendly than o.T.	55	0	3,84	4,00	4	,220
Sustainability aspects of n.T. not explained to community	55	0	3,42	3,00	3	,297
Marketing exaggerates environmentally friendliness	55	0	3,49	3,00	4	,331
Limited individual learning capacity or ability	55	0	3,84	3,00	2[a]	,169
Not enough resource to access training	55	0	3,27	3,00	3	,275
Not sufficient resources & guidance for learning n.T.	55	0	3,64	4,00	2	,148
Way of using very different compared to o.T.	55	0	3,47	3,00	2	,463
No community expert group created for n.T.	55	0	3,64	3,00	3	,342
No possibilities for experiencing n.T. in industry	55	0	3,42	3,00	2	,795
High switching costs and learning efforts	55	0	2,69	2,00	2	,721
Learning efforts within industry are expensive.	55	0	3,42	3,00	3	,229

Table K-15 – Tendencies of barrier items in pharma and biotech

Statistics of Likert-type items for barriers perceived by telecommunication industry experts

	N		Mean	Median	Mode	Skewness
	Valid	M				
Utility perceived to be less than o.T.	100	0	4,44	5,00	6	-,568
n.T. fails to exceed measurable specifications of o.T.	100	0	4,34	5,00	6	-,239
Complexity focuses attention on overall effectiveness	100	0	3,73	3,00	2[a]	,193
Complex radically n.T. cannot be introduced frequently	100	0	3,06	3,00	2	,785
Complementarity of o.T. results in higher total utility	100	0	3,30	3,00	3	,567
No dominant design within an industry compared to o.T.	100	0	3,61	3,00	3	,303
Not adaptable and not perceived to be future-ready	100	0	3,93	4,00	3	-,088
n.T. not adaptable to community needs	100	0	4,39	5,00	6	-,324
Cannot be adapted to other industries	100	0	4,14	4,00	3	,035
Individuals face difficulties in accessing n.T.	100	0	3,78	4,00	3	,138
Access is granted to small social groups	100	0	4,05	4,00	3	,076
Access is restricted by external institutions (e.g. government)	100	0	4,60	4,00	4	-,308
Personal orientations towards its use are negative.	100	0	4,51	5,00	5	-,431
Community of users is towards o.T.	100	0	4,12	4,00	3	,112
Missing industry collaboration	100	0	4,37	5,00	6	-,262
Contagion not strong enough to displace community norms.	100	0	3,99	4,00	3	,068
Poor execution of marketing	100	0	3,29	3,00	2	,583
Not perceived as more environmentally friendly than o.T.	100	0	4,54	4,50	4	-,076
Sustainability aspects of n.T. not explained to community	100	0	3,93	4,00	3	,191
Marketing exaggerates environmentally friendliness	100	0	3,53	3,00	3	,687
Limited individual learning capacity or ability	100	0	4,30	5,00	6	-,384
Not enough resource to access training	100	0	3,80	3,00	3	,311
Not sufficient resources & guidance for learning n.T.	100	0	4,00	4,00	3	,085
Way of using very different compared to o.T.	100	0	4,01	4,00	3	-,124
No community expert group created for n.T.	100	0	4,34	4,50	3	-,034
No possibilities for experiencing n.T. in industry	100	0	3,86	4,00	3	,145
High switching costs and learning efforts	100	0	2,84	3,00	2	,860
Learning efforts within industry are expensive.	100	0	3,70	3,00	3	,300

Table K-16 – Tendencies of barrier items in telecommunication

Statistics of Likert-type scales for barriers perceived by Aeronautics, Defence & Space experts

	N		Mean	Median	Mode	Std. Deviation
	Valid	Missing				
Technology - Utility	46	0	4,4348	4,5000	4,50	1,23202
Technology - Complexity	46	0	3,3043	3,2500	3,00[a]	,89739
Technology - Complementarity	46	0	3,1848	3,0000	2,50	,90283
Technology - Adaptability	46	0	4,1449	4,0000	4,00	1,06493
Social Structure - Social context	46	0	3,9203	3,8333	3,67	1,03084
Social Structure - Orientations	46	0	3,9058	4,0000	3,67[a]	1,09016
Social Structure - Contagion	46	0	3,3804	3,5000	4,00	1,03915
Social Structure - Environmental Awareness	46	0	3,9348	3,6667	3,67	1,09007
Learning - Learning capacity	46	0	3,9058	3,8333	2,67[a]	1,17518
Learning - Learning capability	46	0	3,8261	3,6667	3,00	,99564
Learning - Costs of learning	46	0	3,0000	3,0000	2,50	1,21564

a. Multiple modes exist. The smallest value is shown

Table K-17 – Tendencies of barrier variables in aeronautics, defence & space

Statistics of Likert-type scales for barriers perceived by automotive experts

	N		Mean	Median	Mode	Std. Deviation
	Valid	Missing				
Technology - Utility	111	0	4,2793	4,5000	4,00	1,30503
Technology - Complexity	111	0	3,2297	3,0000	3,50	1,22434
Technology - Complementarity	111	0	3,2928	3,0000	3,00[a]	1,13712
Technology - Adaptability	111	0	4,0541	4,0000	3,33	1,14110
Social Structure - Social context	111	0	3,8709	3,6667	3,67	1,19356
Social Structure - Orientations	111	0	4,0661	4,0000	4,00	1,07855
Social Structure - Contagion	111	0	3,4550	3,5000	3,50	1,08826
Social Structure - Environmental Awareness	111	0	3,8468	3,6667	3,00[a]	1,03649
Learning - Learning capacity	111	0	3,9159	3,6667	3,33[a]	1,13215
Learning - Learning capability	111	0	3,7477	3,6667	3,33	1,14169
Learning - Costs of learning	111	0	3,2838	3,0000	2,50	1,26961

a. Multiple modes exist. The smallest value is shown

Table K-18 – Tendencies of barrier variables in automotive

Statistics of Likert-type scales for barriers perceived by automotive experts for industrial goods

	N		Mean	Median	Mode	Std. Deviation
	Valid	Missing				
Technology - Utility	65	0	4,2308	4,5000	4,00[a]	1,31124
Technology - Complexity	65	0	3,3846	3,5000	3,50	1,22720
Technology - Complementarity	65	0	3,3769	3,5000	3,00	1,10408
Technology - Adaptability	65	0	4,1795	4,0000	3,33[a]	1,04595
Social Structure - Social context	65	0	3,9538	4,0000	4,33	1,21746
Social Structure - Orientations	65	0	4,0769	4,0000	4,67	,98561
Social Structure - Contagion	65	0	3,5538	3,5000	3,50	1,10441
Social Structure - Environmental Awareness	65	0	3,9333	4,0000	3,33[a]	1,11679
Learning - Learning capacity	65	0	3,9077	3,6667	3,67	1,10947
Learning - Learning capability	65	0	3,8359	4,0000	3,33	1,13670
Learning - Costs of learning	65	0	3,4692	3,5000	2,50	1,31659

a. Multiple modes exist. The smallest value is shown

Table K-19 – Tendencies of barrier variables in automotive (B2B)

Statistics of Likert-type items for barriers perceived by automotive experts for consumer goods

	N		Mean	Median	Mode	Std. Deviation
	Valid	Missing				
Technology - Utility	44	0	4,3295	4,5000	3,00[a]	1,32482
Technology - Complexity	44	0	3,0227	3,0000	2,00	1,21500
Technology - Complementarity	44	0	3,1932	3,2500	3,50	1,20665
Technology - Adaptability	44	0	3,9091	3,8333	3,33	1,26851
Social Structure - Social context	44	0	3,7348	3,6667	3,33[a]	1,14024
Social Structure - Orientations	44	0	4,0758	4,0000	4,00	1,21758
Social Structure - Contagion	44	0	3,3409	3,2500	3,50	1,07710
Social Structure - Environmental Awareness	44	0	3,7273	3,6667	3,00[a]	,91858
Learning - Learning capacity	44	0	3,9091	3,8333	3,33[a]	1,17986
Learning - Learning capability	44	0	3,6439	3,6667	3,67	1,14436
Learning - Costs of learning	44	0	3,0114	3,0000	3,50	1,17873

a. Multiple modes exist. The smallest value is shown

Table K-20 – Tendencies of barrier variables in automotive (B2C)

Statistics of Likert-type scales for barriers perceived by chemicals industry experts

	N		Mean	Median	Mode	Std. Deviation
	Valid	Missing				
Technology - Utility	65	0	4,2077	4,0000	4,00	1,22759
Technology - Complexity	65	0	3,2692	3,0000	4,00	1,13563
Technology - Complementarity	65	0	3,3000	3,5000	3,00	,99137
Technology - Adaptability	65	0	4,1641	4,3333	4,67[a]	1,07226
Social Structure - Social context	65	0	4,0615	4,0000	4,00	1,07188
Social Structure - Orientations	65	0	4,0872	4,0000	3,33	1,04296
Social Structure - Contagion	65	0	3,3692	3,5000	3,00[a]	1,12249
Social Structure - Environmental Awareness	65	0	3,9949	4,0000	4,67	1,12653
Learning - Learning capacity	65	0	3,8974	4,0000	3,33	1,13945
Learning - Learning capability	65	0	3,8923	3,6667	3,33	1,11197
Learning - Costs of learning	65	0	3,3615	3,0000	3,00	1,27631

a. Multiple modes exist. The smallest value is shown

Table K-21 – Tendencies of barrier variables in chemicals

Statistics of Likert-type scales for barriers perceived by consumer electronics industry experts

	N		Mean	Median	Mode	Std. Deviation
	Valid	Missing				
Technology - Utility	50	0	4,2500	4,5000	4,50	1,10310
Technology - Complexity	50	0	3,4400	3,5000	2,50	1,27231
Technology - Complementarity	50	0	3,6000	3,5000	4,00	,83299
Technology - Adaptability	50	0	4,2533	4,3333	4,67	,99787
Social Structure - Social context	50	0	3,9533	4,0000	3,33	1,11272
Social Structure - Orientations	50	0	4,1600	4,1667	4,00[a]	1,02185
Social Structure - Contagion	50	0	3,5900	3,5000	3,50	,95666
Social Structure - Environmental Awareness	50	0	3,7400	3,6667	2,67[a]	1,01304
Learning - Learning capacity	50	0	3,7667	3,6667	3,67[a]	1,22382
Learning - Learning capability	50	0	4,0067	4,0000	4,33	1,13787
Learning - Costs of learning	50	0	3,7600	3,5000	3,50	1,42585

a. Multiple modes exist. The smallest value is shown

Table K-22 – Tendencies of barrier variables in consumer electronics

Statistics of Likert-type scales for barriers perceived by electric/electronic manufacturing experts

	N		Mean	Median	Mode	Std. Deviation
	Valid	Missing				
Technology - Utility	71	0	4,5141	4,5000	4,50[a]	1,30102
Technology - Complexity	71	0	3,4718	3,5000	4,00	1,10805
Technology - Complementarity	71	0	3,5282	3,5000	2,50	1,14295
Technology - Adaptability	71	0	4,2629	4,3333	4,00	1,08367
Social Structure - Social context	71	0	4,3099	4,3333	4,33	1,17827
Social Structure - Orientations	71	0	4,0563	4,0000	4,33	1,02040
Social Structure - Contagion	71	0	3,5563	3,5000	4,00	1,03699
Social Structure - Environmental Awareness	71	0	3,9577	4,0000	3,33	1,07486
Learning - Learning capacity	71	0	3,8498	3,6667	3,33	1,11525
Learning - Learning capability	71	0	3,9061	3,6667	3,33[a]	1,00977
Learning - Costs of learning	71	0	3,5070	3,5000	4,00	1,22909

a. Multiple modes exist. The smallest value is shown

Table K-23 – Tendencies of barrier variables in electr. /electronic manufacturing

Statistics of Likert-type scales for barriers perceived by information technology industry experts

	N		Mean	Median	Mode	Std. Deviation
	Valid	Missing				
Technology - Utility	76	0	4,6908	5,0000	4,00	1,26482
Technology - Complexity	76	0	3,4868	3,5000	3,00	1,25956
Technology - Complementarity	76	0	3,5461	3,5000	4,00	1,16955
Technology - Adaptability	76	0	4,5921	4,6667	5,00	1,26678
Social Structure - Social context	76	0	4,2325	4,3333	4,67	1,18761
Social Structure - Orientations	76	0	4,1754	4,0000	4,00	1,03204
Social Structure - Contagion	76	0	3,4342	3,2500	2,50	1,33002
Social Structure - Environmental Awareness	76	0	3,8991	4,0000	4,00	1,08869
Learning - Learning capacity	76	0	3,8904	3,6667	3,67	1,17302
Learning - Learning capability	76	0	3,9035	4,0000	4,33	1,17229
Learning - Costs of learning	76	0	3,5132	3,5000	3,00	1,32658

Table K-24 – Tendencies of barrier variables in IT industry

Statistics of Likert-type scales for barriers perceived by medical industry experts

	N		Mean	Median	Mode	Std. Deviation
	Valid	Missing				
Technology - Utility	117	0	4,2222	4,5000	4,00	1,54033
Technology - Complexity	117	0	3,3675	3,0000	2,50	1,32026
Technology - Complementarity	117	0	3,5684	3,5000	3,00	1,29971
Technology – Adaptability	117	0	4,0712	4,0000	3,33	1,17430
Social Structure – Social context	117	0	3,7521	3,6667	2,67	1,19958
Social Structure - Orientations	117	0	4,1111	4,0000	4,00	1,13462
Social Structure – Contagion	117	0	3,4530	3,5000	3,50	1,15405
Social Structure - Environmental Awareness	117	0	3,9031	4,0000	4,00	1,05415
Learning – Learning capacity	117	0	3,9487	4,0000	4,00	1,27653
Learning – Learning capability	117	0	3,9345	3,6667	3,67	1,25124
Learning – Costs of learning	117	0	3,2350	3,0000	4,00	1,36390

Table K-25 – Tendencies of barrier variables in medical industry

Statistics of Likert-type scales for barriers perceived by medical experts for industrial goods

	N		Mean	Median	Mode	Std. Deviation
	Valid	Missing				
Technology - Utility	66	0	4,1515	4,2500	5,50	1,51396
Technology - Complexity	66	0	3,4091	3,0000	2,50	1,28275
Technology - Complementarity	66	0	3,6439	3,5000	3,00	1,24581
Technology - Adaptability	66	0	4,1414	4,0000	3,67	1,06708
Social Structure - Social context	66	0	3,8333	3,6667	4,67	1,26930
Social Structure - Orientations	66	0	4,0556	4,0000	4,00	1,12407
Social Structure - Contagion	66	0	3,3333	3,5000	3,50	1,04268
Social Structure - Environmental Awareness	66	0	3,9596	4,0000	4,00	,92175
Learning - Learning capacity	66	0	4,0101	4,0000	4,00	1,23616
Learning - Learning capability	66	0	3,9747	3,6667	3,67	1,25175
Learning - Costs of learning	66	0	3,1894	3,2500	4,00	1,23651

Table K-26 – Tendencies of barrier variables in medical industry (B2B)

Statistics of Likert-type scales for barriers perceived by medical experts for consumer goods

	N		Mean	Median	Mode	Std. Deviation
	Valid	Missing				
Technology - Utility	50	0	4,3100	4,5000	4,00	1,60003
Technology - Complexity	50	0	3,3000	3,0000	2,50	1,38873
Technology - Complementarity	50	0	3,5000	3,2500	2,50	1,37024
Technology - Adaptability	50	0	3,9667	3,6667	2,67	1,31492
Social Structure - Social context	50	0	3,6400	3,6667	2,67	1,11644
Social Structure - Orientations	50	0	4,1733	4,0000	5,00	1,16495
Social Structure - Contagion	50	0	3,6000	3,5000	2,00[a]	1,28968
Social Structure - Environmental Awareness	50	0	3,7933	3,6667	2,67[a]	1,19312
Learning - Learning capacity	50	0	3,8467	4,0000	4,00	1,33878
Learning - Learning capability	50	0	3,8400	3,6667	3,00	1,23670
Learning - Costs of learning	50	0	3,2700	3,0000	2,00	1,52934

a. Multiple modes exist. The smallest value is shown

Table K-27 – Tendencies of barrier variables in medical industry (B2C)

Statistics of Likert-type scales for barriers perceived by pharmaceutical and biotechnology experts

	N		Mean	Median	Mode	Std. Deviation
	Valid	Missing				
Technology - Utility	55	0	3,9364	4,0000	5,00	1,68889
Technology - Complexity	55	0	3,1727	3,0000	2,50[a]	1,25543
Technology - Complementarity	55	0	3,2545	3,0000	2,50	1,21287
Technology - Adaptability	55	0	3,7333	3,6667	4,33	1,19567
Social Structure - Social context	55	0	3,3636	3,3333	3,00	1,30884
Social Structure - Orientations	55	0	3,5818	3,3333	3,33	1,28495
Social Structure - Contagion	55	0	3,0545	3,0000	2,50	1,27538
Social Structure - Environmental Awareness	55	0	3,5818	3,3333	3,33	1,20393
Learning - Learning capacity	55	0	3,5818	3,3333	3,33	1,26070
Learning - Learning capability	55	0	3,5091	3,3333	3,00	1,19645
Learning - Costs of learning	55	0	3,0545	3,0000	2,00	1,37663

a. Multiple modes exist. The smallest value is shown

Table K-28 – Tendencies of barrier variables in pharma and biotech

Statistics of Likert-type scales for barriers perceived by telecommunication industry experts

	N		Mean	Median	Mode	Std. Deviation
	Valid	Missing				
Technology - Utility	100	0	4,3900	4,5000	4,00	1,38276
Technology - Complexity	100	0	3,3950	3,0000	2,50	1,36014
Technology - Complementarity	100	0	3,4550	3,5000	3,00[a]	1,18512
Technology - Adaptability	100	0	4,1533	4,3333	4,33[a]	1,09424
Social Structure - Social context	100	0	4,1433	4,3333	4,33	1,16655
Social Structure - Orientations	100	0	4,3333	4,3333	5,33	1,20976
Social Structure - Contagion	100	0	3,6400	3,5000	3,00	1,24333
Social Structure - Environmental Awareness	100	0	4,0000	4,0000	4,00	,96980
Learning - Learning capacity	100	0	4,0333	4,0000	3,67	1,22222
Learning - Learning capability	100	0	4,0700	4,1667	4,67	1,15984
Learning - Costs of learning	100	0	3,2700	3,0000	3,00	1,29961

a. Multiple modes exist. The smallest value is shown

Table K-29 – Tendencies of barrier variables in telecommunication

Appendix L. Normality distribution for survey analysis

Tests of Normality with items representing barriers aspects

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Utility perceived to be less than o.T.	,199	920	,000	,918	920	,000
n.T. fails to exceed measurable specifications of o.T.	,175	920	,000	,918	920	,000
Complexity focuses attention on overall effectiveness	,214	920	,000	,913	920	,000
Complex radically n.T. cannot be introduced frequently	,228	920	,000	,871	920	,000
Complementarity of o.T. results in higher total utility	,199	920	,000	,929	920	,000
No dominant design within an industry compared to o.T.	,225	920	,000	,915	920	,000
Not adaptable and not perceived to be future-ready	,161	920	,000	,943	920	,000
n.T. not adaptable to community needs	,165	920	,000	,925	920	,000
Cannot be adapted to other industries	,150	920	,000	,938	920	,000
Individuals face difficulties in accessing n.T.	,196	920	,000	,932	920	,000
Access is granted to small social groups	,176	920	,000	,936	920	,000
Access is restricted by external institutions (e.g. government)	,180	920	,000	,928	920	,000
Personal orientations towards its use are negative.	,152	920	,000	,933	920	,000
Community of users is towards o.T.	,222	920	,000	,923	920	,000
Missing industry collaboration	,173	920	,000	,927	920	,000
Contagion not strong enough to displace community norms.	,205	920	,000	,926	920	,000
Poor execution of marketing	,201	920	,000	,903	920	,000
Not perceived as more environmentally friendly than o.T.	,160	920	,000	,942	920	,000
Sustainability aspects of n.T. not explained to community	,192	920	,000	,930	920	,000
Marketing exaggerates environmentally friendliness	,170	920	,000	,942	920	,000
Limited individual learning capacity or ability	,176	920	,000	,924	920	,000
Not enough resource to access training	,225	920	,000	,925	920	,000
Not sufficient resources & guidance for learning n.T.	,194	920	,000	,930	920	,000
Way of using very different compared to o.T.	,175	920	,000	,927	920	,000
No community expert group created for n.T.	,175	920	,000	,927	920	,000
No possibilities for experiencing n.T. in industry	,227	920	,000	,911	920	,000
High switching costs and learning efforts	,217	920	,000	,894	920	,000
Learning efforts within industry are expensive.	,191	920	,000	,931	920	,000

a. Lilliefors Significance Correction

Table L-1 – Normality test results of barrier items

Tests of Normality with scales representing barrier variables

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Technology - Utility	,099	920	,000	,971	920	,000
Technology - Complexity	,129	920	,000	,960	920	,000
Technology - Complementarity	,117	920	,000	,965	920	,000
Technology - Adaptability	,069	920	,000	,988	920	,000
Social Structure - Social context	,083	920	,000	,989	920	,000
Social Structure - Orientations	,068	920	,000	,989	920	,000
Social Structure - Contagion	,108	920	,000	,967	920	,000
Social Structure - Environmental Awareness	,077	920	,000	,989	920	,000
Learning - Learning capacity	,080	920	,000	,988	920	,000
Learning - Learning capability	,088	920	,000	,985	920	,000
Learning - Costs of learning	,118	920	,000	,966	920	,000

a. Lilliefors Significance Correction

Table L-2 – Normality test results of barrier variables

Appendix M. Variation test results for survey analysis

Test Statistics[a,b]: Coefficients for item variation with job position

	Chi-Square	df	Asymp. Sig.
Utility perceived to be less than o.T.	10,799	4	,029
n.T. fails to exceed measurable specifications of o.T.	5,770	4	,217
Complexity focuses attention on overall effectiveness	1,712	4	,789
Complex radically n.T. cannot be introduced frequently	5,276	4	,260
Complementarity of o.T. results in higher total utility	4,184	4	,382
No dominant design within an industry compared to o.T.	4,974	4	,290
Not adaptable and not perceived to be future-ready	3,138	4	,535
n.T. not adaptable to community needs	3,378	4	,497
Cannot be adapted to other industries	3,360	4	,500
Individuals face difficulties in accessing n.T.	1,471	4	,832
Access is granted to small social groups	4,617	4	,329
Access is restricted by external institutions (e.g. government)	4,606	4	,330
Personal orientations towards its use are negative.	6,769	4	,149
Community of users is towards o.T.	3,210	4	,523
Missing industry collaboration	2,223	4	,695
Contagion not strong enough to displace community norms.	6,035	4	,197
Poor execution of marketing	5,208	4	,267
Not perceived as more environmentally friendly than o.T.	,991	4	,911
Sustainability aspects of n.T. not explained to community	3,527	4	,474
Marketing exaggerates environmentally friendliness	3,856	4	,426
Limited individual learning capacity or ability	1,263	4	,868
Not enough resource to access training	1,530	4	,821
Not sufficient resources & guidance for learning n.T.	7,188	4	,126
Way of using very different compared to o.T.	7,882	4	,096
No community expert group created for n.T.	1,756	4	,780
No possibilities for experiencing n.T. in industry	3,585	4	,465
High switching costs and learning efforts	2,141	4	,710
Learning efforts within industry are expensive.	,748	4	,945

a. Kruskal Wallis Test

b. Grouping Variable: Job position

Table M-1 – Barrier item variation due to different job positions

Test Statistics[a,b]: Coefficients for item variation with different educational background

	Chi-Square	df	Asymp. Sig.
Utility perceived to be less than o.T.	2,513	4	,642
n.T. fails to exceed measurable specifications of o.T.	1,647	4	,800
Complexity focuses attention on overall effectiveness	2,401	4	,662
Complex radically n.T. cannot be introduced frequently	7,255	4	,123
Complementarity of o.T. results in higher total utility	3,476	4	,482
No dominant design within an industry compared to o.T.	,300	4	,990
Not adaptable and not perceived to be future-ready	1,631	4	,803
n.T. not adaptable to community needs	3,424	4	,490
Cannot be adapted to other industries	,674	4	,955
Individuals face difficulties in accessing n.T.	5,066	4	,281
Access is granted to small social groups	1,139	4	,888
Access is restricted by external institutions (e.g. government)	5,492	4	,240
Personal orientations towards its use are negative.	4,164	4	,384
Community of users is towards o.T.	,790	4	,940
Missing industry collaboration	1,923	4	,750
Contagion not strong enough to displace community norms.	1,553	4	,817
Poor execution of marketing	1,988	4	,738
Not perceived as more environmentally friendly than o.T.	2,447	4	,654
Sustainability aspects of n.T. not explained to community	4,653	4	,325
Marketing exaggerates environmentally friendliness	1,755	4	,781
Limited individual learning capacity or ability	2,013	4	,733
Not enough resource to access training	2,968	4	,563
Not sufficient resources & guidance for learning n.T.	3,841	4	,428
Way of using very different compared to o.T.	4,741	4	,315
No community expert group created for n.T.	2,988	4	,560
No possibilities for experiencing n.T. in industry	4,902	4	,298
High switching costs and learning efforts	4,642	4	,326
Learning efforts within industry are expensive.	5,110	4	,276

a. Kruskal Wallis Test

b. Grouping Variable: Education

Table M-2 – Barrier item variation due to different educational background

Test Statistics[a,b]: Coefficients for item variation with different Company sizes

	Chi-Square	df	Asymp. Sig.
Utility perceived to be less than o.T.	8,908	7	,259
n.T. fails to exceed measurable specifications of o.T.	8,987	7	,254
Complexity focuses attention on overall effectiveness	4,900	7	,672
Complex radically n.T. cannot be introduced frequently	4,437	7	,728
Complementarity of o.T. results in higher total utility	6,283	7	,507
No dominant design within an industry compared to o.T.	2,636	7	,917
Not adaptable and not perceived to be future-ready	9,049	7	,249
n.T. not adaptable to community needs	14,267	7	,047
Cannot be adapted to other industries	6,154	7	,522
Individuals face difficulties in accessing n.T.	7,740	7	,356
Access is granted to small social groups	3,730	7	,810
Access is restricted by external institutions (e.g. government)	8,280	7	,309
Personal orientations towards its use are negative.	7,075	7	,421
Community of users is towards o.T.	4,922	7	,670
Missing industry collaboration	5,360	7	,616
Contagion not strong enough to displace community norms.	6,394	7	,495
Poor execution of marketing	8,376	7	,301
Not perceived as more environmentally friendly than o.T.	3,864	7	,795
Sustainability aspects of n.T. not explained to community	8,312	7	,306
Marketing exaggerates environmentally friendliness	5,338	7	,619
Limited individual learning capacity or ability	4,707	7	,696
Not enough resource to access training	5,061	7	,652
Not sufficient resources & guidance for learning n.T.	10,182	7	,178
Way of using very different compared to o.T.	6,175	7	,520
No community expert group created for n.T.	10,141	7	,181
No possibilities for experiencing n.T. in industry	3,767	7	,806
High switching costs and learning efforts	9,598	7	,212
Learning efforts within industry are expensive.	4,121	7	,766

a. Kruskal Wallis Test

b. Grouping Variable: Total number of employees

Table M-3 – Barrier item variation due to company size, the respondent works for

Test Statistics[a]: Coefficients for item variation with different economic regions

	Mann-Whitney U	Wilcoxon W	Z	Asymp. Sig. (2-tailed)
Utility perceived to be less than o.T.	80553,500	132234,500	-1,324	,185
n.T. fails to exceed measurable specifications of o.T.	83197,000	223912,000	-,548	,584
Complexity focuses attention on overall effectiveness	78404,500	130085,500	-1,958	,050
Complex radically n.T. cannot be introduced frequently	81385,500	222100,500	-1,095	,273
Complementarity of o.T. results in higher total utility	77009,500	128690,500	-2,383	,017
No dominant design within an industry compared to o.T.	82832,500	223547,500	-,659	,510
Not adaptable and not perceived to be future-ready	79097,000	130778,000	-1,746	,081
n.T. not adaptable to community needs	79335,500	131016,500	-1,681	,093
Cannot be adapted to other industries	81356,000	133037,000	-1,084	,278
Individuals face difficulties in accessing n.T.	66853,000	118534,000	-5,343	,000
Access is granted to small social groups	73720,000	125401,000	-3,328	,001
Access is restricted by external institutions (e.g. government)	68236,000	119917,000	-4,929	,000
Personal orientations towards its use are negative.	79905,000	131586,000	-1,514	,130
Community of users is towards o.T.	82101,500	222816,500	-,873	,383
Missing industry collaboration	80164,000	220879,000	-1,437	,151
Contagion not strong enough to displace community norms.	83235,500	223950,500	-,539	,590
Poor execution of marketing	76225,000	127906,000	-2,610	,009
Not perceived as more environmentally friendly than o.T.	80047,000	131728,000	-1,476	,140
Sustainability aspects of n.T. not explained to community	76032,000	127713,000	-2,645	,008
Marketing exaggerates environmentally friendliness	74956,000	126637,000	-2,973	,003
Limited individual learning capacity or ability	72896,000	124577,000	-3,570	,000
Not enough resource to access training	77530,000	129211,000	-2,226	,026
Not sufficient resources & guidance for learning n.T.	78539,500	130220,500	-1,915	,056
Way of using very different compared to o.T.	81053,000	132734,000	-1,174	,240
No community expert group created for n.T.	79511,000	131192,000	-1,624	,104
No possibilities for experiencing n.T. in industry	79060,000	130741,000	-1,770	,077
High switching costs and learning efforts	78333,500	130014,500	-1,991	,046
Learning efforts within industry are expensive.	80154,500	131835,500	-1,439	,150

a. Grouping Variable: Economic Region (developed and emerging countries)

Table M-4 – Barrier item variation due to different economic regions

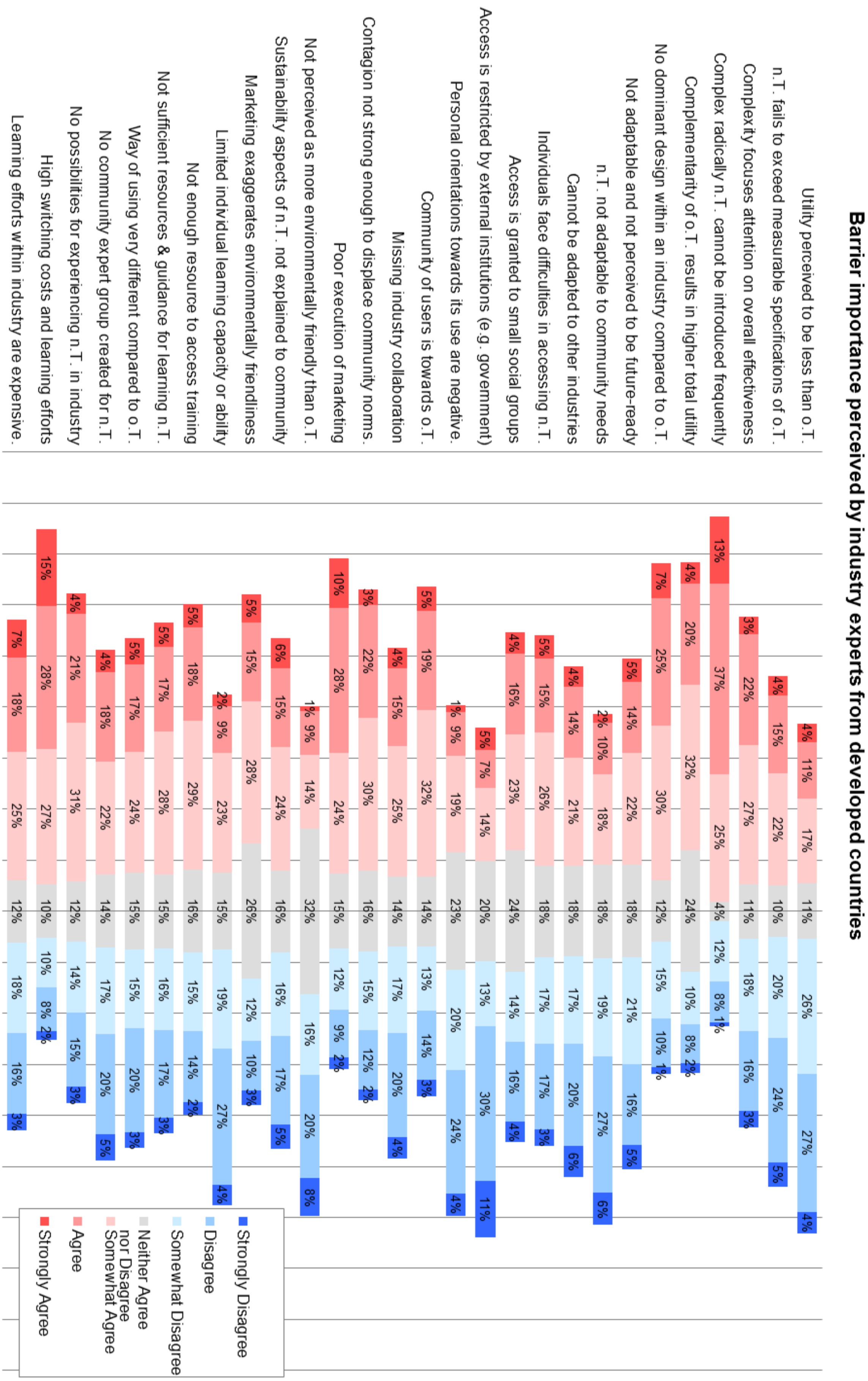

Figure M-1 – Frequency of barrier item perceptions from developed countries

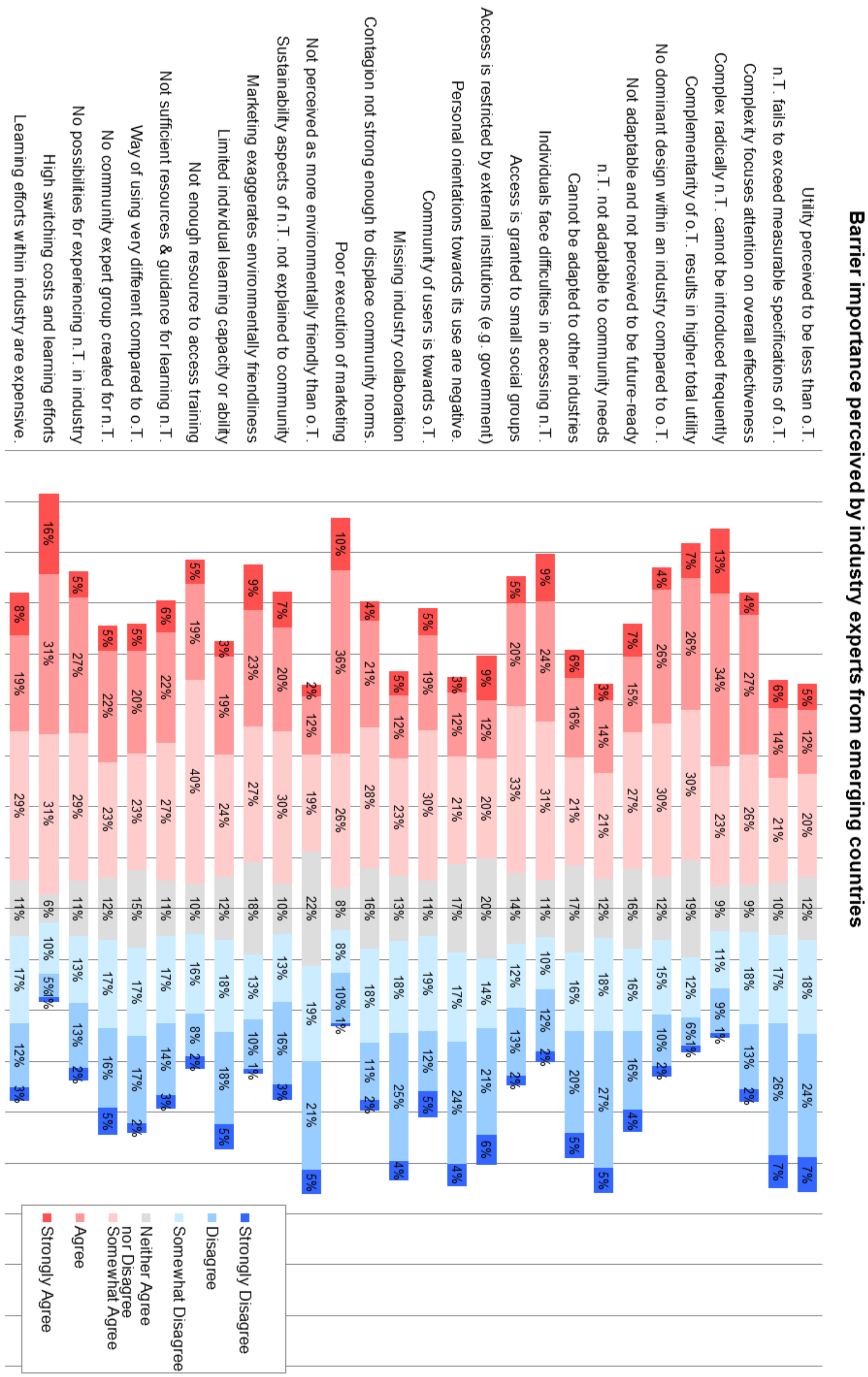

Figure M-2 – Frequency of barrier item perceptions from emerging countries

Test Statistics[a]: Coefficients for scale variation with different economic regions

	Mann-Whitney U	Wilcoxon W	Z	Asymp. Sig. (2-tailed)
Technology - Utility	83396,500	135077,500	-,483	,629
Technology - Complexity	83183,000	134864,000	-,546	,585
Technology - Complementarity	81411,000	133092,000	-1,061	,289
Technology - Adaptability	77469,500	129150,500	-2,193	,028
Social Structure - Social context	63178,000	114859,000	-6,320	,000
Social Structure - Orientations	82129,500	222844,500	-,848	,397
Social Structure - Contagion	81530,000	133211,000	-1,027	,305
Social Structure - Environmental Awareness	74972,500	126653,500	-2,917	,004
Learning - Learning capacity	73827,000	125508,000	-3,245	,001
Learning - Learning capability	79932,500	131613,500	-1,483	,138
Learning - Costs of learning	78467,000	130148,000	-1,912	,056

a. Grouping Variable: Economic Region

Table M-5 – Barrier variable variation due to different economic regions

Statistics: Barrier variables of the subgroup of developing regions

	N		Mean	Median	Mode	Std. Deviation
	Valid	Missing				
Technology - Utility	530	0	4,3132	4,5000	4,00	1,35028
Technology - Complexity	530	0	3,3481	3,0000	2,50	1,23934
Technology - Complementarity	530	0	3,4217	3,5000	3,00[a]	1,11740
Technology - Adaptability	530	0	4,2214	4,3333	4,00	1,14081
Social Structure - Social context	530	0	4,1509	4,0000	3,67	1,16712
Social Structure - Orientations	530	0	4,0214	4,0000	3,67	1,11263
Social Structure - Contagion	530	0	3,4481	3,5000	3,00	1,17659
Social Structure - Environmental Awareness	530	0	4,0057	4,0000	4,00	1,07548
Learning - Learning capacity	530	0	3,9698	4,0000	3,67	1,19032
Learning - Learning capability	530	0	3,8648	3,6667	3,33	1,15632
Learning - Costs of learning	530	0	3,3953	3,0000	3,00	1,32693

a. Multiple modes exist. The smallest value is shown

Table M-6 – General statistics of barrier variables of developed regions

Statistics: Barrier variables of the subgroup of emerging regions

	N		Mean	Median	Mode	Std. Deviation
	Valid	Missing				
Technology - Utility	321	0	4,2523	4,5000	4,50	1,38920
Technology - Complexity	321	0	3,2975	3,0000	2,00[a]	1,24479
Technology - Complementarity	321	0	3,3520	3,0000	2,50	1,15613
Technology - Adaptability	321	0	4,0447	4,0000	4,33	1,18574
Social Structure - Social context	321	0	3,6490	3,3333	3,33	1,14869
Social Structure - Orientations	321	0	4,0509	4,0000	4,67	1,12755
Social Structure - Contagion	321	0	3,3380	3,5000	4,00	1,09627
Social Structure - Environmental Awareness	321	0	3,7529	3,6667	4,33	1,07133
Learning – Learning capacity	321	0	3,6978	3,6667	3,33	1,16177
Learning – Learning capability	321	0	3,6999	3,6667	3,67	1,10221
Learning – Costs of learning	321	0	3,1900	3,0000	3,00	1,22654

a. Multiple modes exist. The smallest value is shown

Table M-7 – General statistics of barrier variables of emerging regions

Correlations of barrier variables with variable of economic regions

	Kendall's tau_b		Spearman's rho	
N = 917	Correlation Coefficient	Sig. (2-tailed)	Correlation Coefficient	Sig. (2-tailed)
Technology - Utility	,003	,923	,003	,916
Technology - Complexity	-,015	,590	-,018	,592
Technology - Complementarity	-,019	,498	-,022	,498
Technology - Adaptability	-,069*	,011	-,084*	,010
Social Structure - Social context	-,155**	,000	-,188**	,000
Social Structure - Orientations	,022	,424	,027	,417
Social Structure - Contagion	-,038	,175	-,044	,178
Social Structure - Environmental Awareness	-,080**	,004	-,096**	,004
Learning - Learning capacity	-,083**	,002	-,100**	,002
Learning - Learning capability	-,032	,235	-,039	,232
Learning - Costs of learning	-,071**	,010	-,085**	,010

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

Table M-8 – Relationship of barrier variables with variable of economic regions

Test Statistics[a,b]: Coefficients for item variation with different technology-intensive industries

	Chi-Square	df	Asymp. Sig.
Utility perceived to be less than o.T.	15,625	8	,048
n.T. fails to exceed measurable specifications of o.T.	5,373	8	,717
Complexity focuses attention on overall effectiveness	7,871	8	,446
Complex radically n.T. cannot be introduced frequently	4,583	8	,801
Complementarity of o.T. results in higher total utility	6,452	8	,597
No dominant design within an industry compared to o.T.	22,046	8	,005
Not adaptable and not perceived to be future-ready	12,588	8	,127
n.T. not adaptable to community needs	9,897	8	,272
Cannot be adapted to other industries	20,146	8	,010
Individuals face difficulties in accessing n.T.	21,528	8	,006
Access is granted to small social groups	17,147	8	,029
Access is restricted by external institutions (e.g. government)	22,414	8	,004
Personal orientations towards its use are negative.	13,899	8	,084
Community of users is towards o.T.	26,993	8	,001
Missing industry collaboration	6,876	8	,550
Contagion not strong enough to displace community norms.	19,717	8	,011
Poor execution of marketing	5,692	8	,682
Not perceived as more environmentally friendly than o.T.	15,079	8	,058
Sustainability aspects of n.T. not explained to community	6,869	8	,551
Marketing exaggerates environmentally friendliness	5,088	8	,748
Limited individual learning capacity or ability	7,395	8	,495
Not enough resource to access training	6,649	8	,575
Not sufficient resources & guidance for learning n.T.	7,340	8	,500
Way of using very different compared to o.T.	8,532	8	,383
No community expert group created for n.T.	11,292	8	,186
No possibilities for experiencing n.T. in industry	13,054	8	,110
High switching costs and learning efforts	14,801	8	,063
Learning efforts within industry are expensive.	10,654	8	,222

a. Kruskal Wallis Test

b. Grouping Variable: Industries

Table M-9 – Barrier item variation due to different technology-intensive industries

Test Statistics[a,b]: Coefficients for scale variation with different technology-intensive industries

	Chi-Square	df	Asymp. Sig.
Technology - Utility	12,116	8	,146
Technology - Complexity	5,029	8	,754
Technology - Complementarity	9,277	8	,319
Technology - Adaptability	21,273	8	,006
Social Structure - Social context	30,703	8	,000
Social Structure - Orientations	14,869	8	,062
Social Structure – Contagion	11,803	8	,160
Social Structure - Environmental Awareness	8,164	8	,418
Learning – Learning capacity	5,989	8	,649
Learning – Learning capability	11,756	8	,162
Learning – Costs of learning	13,823	8	,087

a. Kruskal Wallis Test

b. Grouping Variable: Industries

Table M-10 – Barrier variable variation in different technology-intensive industries

Test Statistics[a]: Coefficients for item variation with types of good

	Mann-Whitney U	Wilcoxon W	Z	Asymp. Sig. (2-tailed)
Utility perceived to be less than o.T.	87810,500	131470,500	-,719	,472
n.T. fails to exceed measurable specifications of o.T.	88956,500	277147,500	-,402	,688
Complexity focuses attention on overall effectiveness	84485,500	128145,500	-1,638	,101
Complex radically n.T. cannot be introduced frequently	86688,500	274879,500	-1,043	,297
Complementarity of o.T. results in higher total utility	86108,000	129768,000	-1,197	,231
No dominant design within an industry compared to o.T.	76856,000	265047,000	-3,759	,000
Not adaptable and not perceived to be future-ready	89784,000	133444,000	-,174	,862
n.T. not adaptable to community needs	85739,000	129399,000	-1,288	,198
Cannot be adapted to other industries	90314,500	278505,500	-,028	,977
Individuals face difficulties in accessing n.T.	83635,500	127295,500	-1,869	,062
Access is granted to small social groups	81644,000	125304,000	-2,416	,016
Access is restricted by external institutions (e.g. government)	84120,500	127780,500	-1,731	,083
Personal orientations towards its use are negative.	86075,500	274266,500	-1,196	,232
Community of users is towards o.T.	79077,000	267268,000	-3,135	,002
Missing industry collaboration	89607,500	133267,500	-,223	,824
Contagion not strong enough to displace community norms.	83621,500	271812,500	-1,879	,060
Poor execution of marketing	89053,500	277244,500	-,378	,706
Not perceived as more environmentally friendly than o.T.	78465,500	122125,500	-3,300	,001
Sustainability aspects of n.T. not explained to community	85111,000	128771,000	-1,459	,144
Marketing exaggerates environmentally friendliness	90186,500	133846,500	-,064	,949
Limited individual learning capacity or ability	87373,000	131033,000	-,838	,402
Not enough resource to access training	84967,500	128627,500	-1,510	,131
Not sufficient resources & guidance for learning n.T.	89138,500	132798,500	-,352	,725
Way of using very different compared to o.T.	89743,500	277934,500	-,185	,853
No community expert group created for n.T.	89219,000	277410,000	-,329	,742
No possibilities for experiencing n.T. in industry	87578,000	275769,000	-,785	,432
High switching costs and learning efforts	82600,000	270791,000	-2,172	,030
Learning efforts within industry are expensive.	89102,000	132762,000	-,362	,717

a. Grouping Variable: Industrial Good

Table M-11 – Barrier item variation due to different types of good

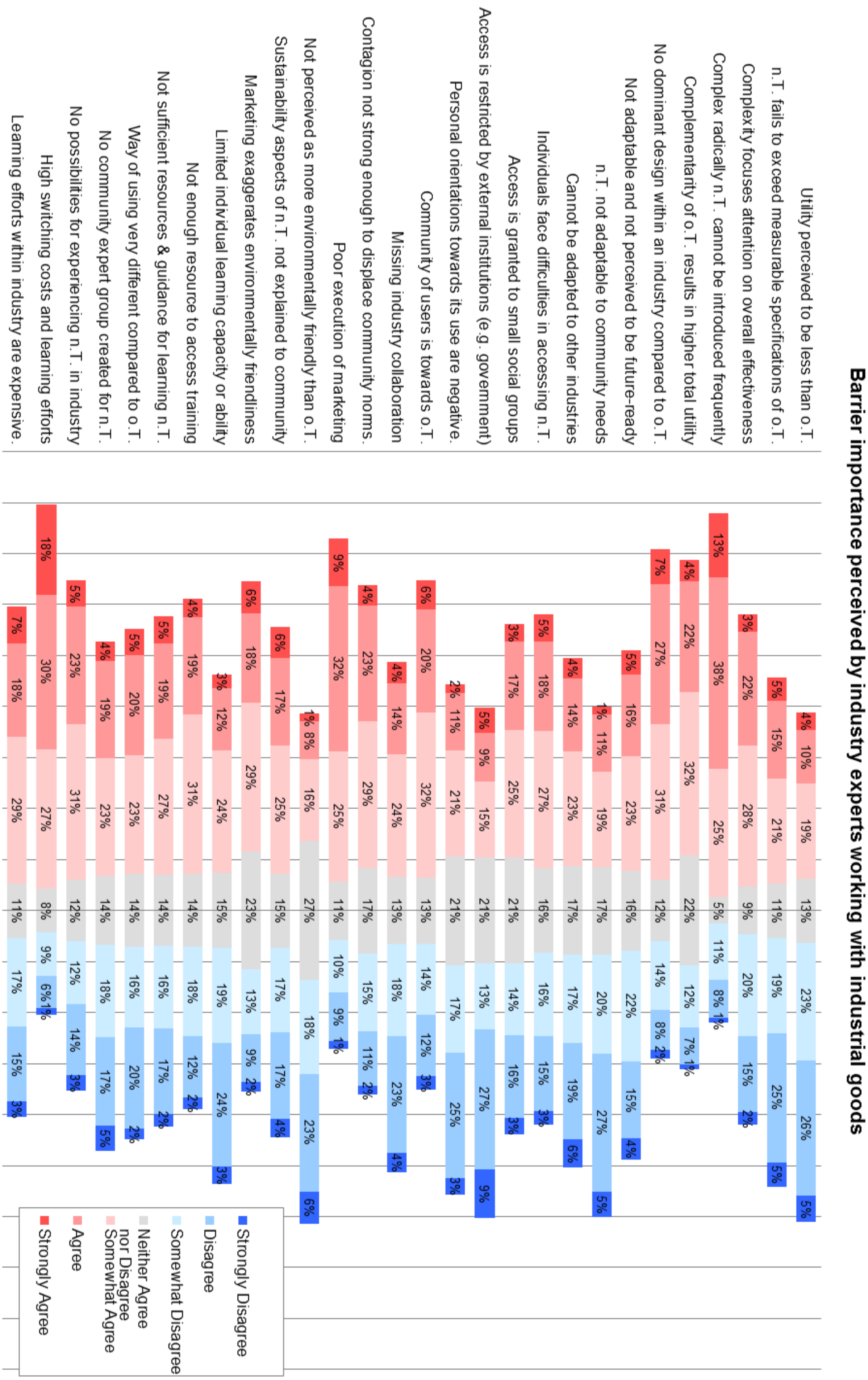

Figure M-3 – Frequency of barrier item perceptions on industrial goods

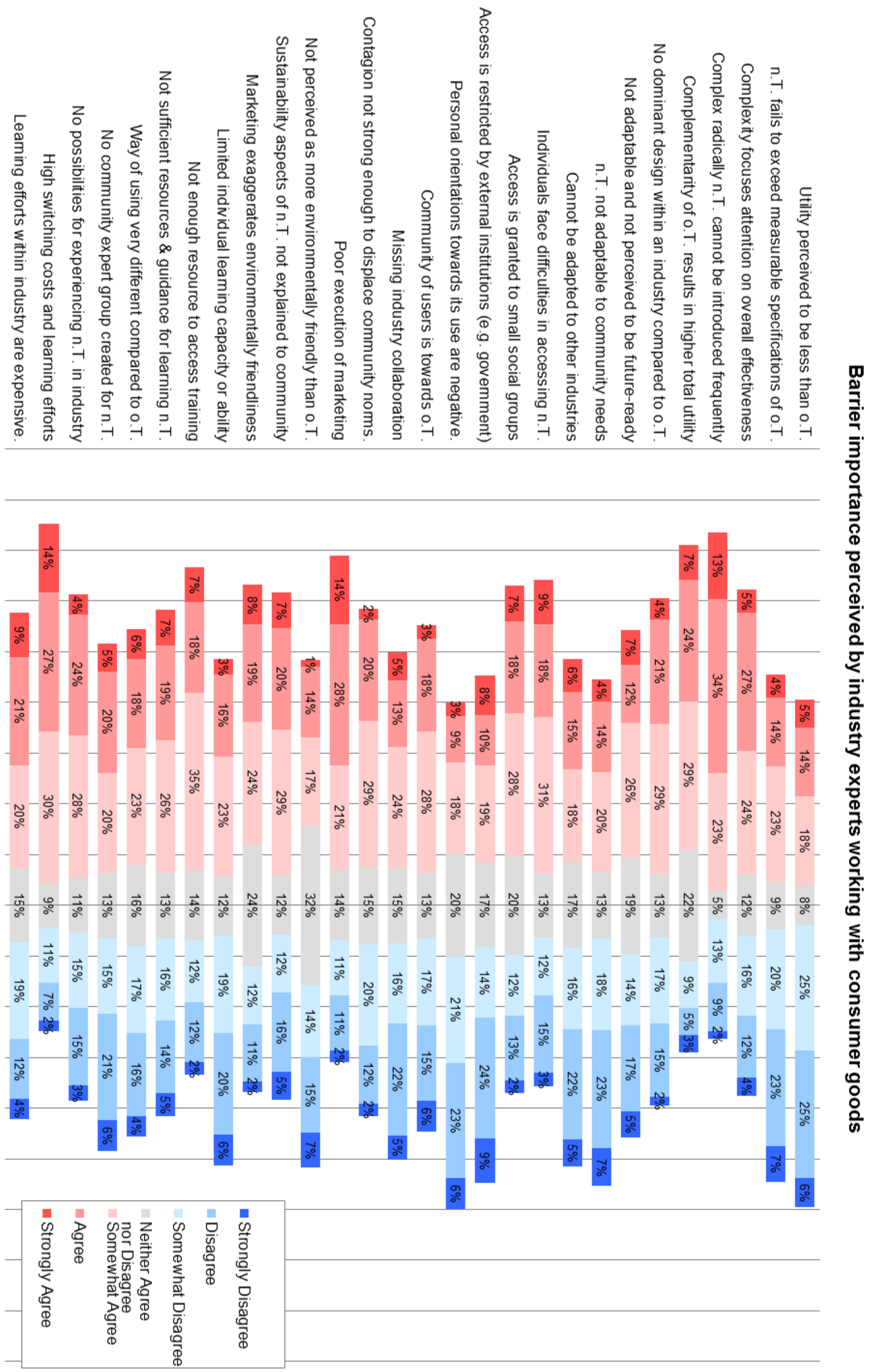

Figure M-4 – Frequency of barrier item perceptions on consumer goods

Test Statistics[a]: Coefficients for scale variation with types of good

	Mann-Whitney U	Wilcoxon W	Z	Asymp. Sig. (2-tailed)
Technology - Utility	89623,500	133283,500	-,216	,829
Technology - Complexity	88395,500	132055,500	-,551	,582
Technology - Complementarity	82385,000	270576,000	-2,189	,029
Technology - Adaptability	87301,000	130961,000	-,845	,398
Social Structure - Social context	80485,000	124145,000	-2,693	,007
Social Structure - Orientations	83527,000	271718,000	-1,869	,062
Social Structure - Contagion	84437,500	272628,500	-1,630	,103
Social Structure - Environmental Awareness	81789,000	125449,000	-2,341	,019
Learning - Learning capacity	86459,500	130119,500	-1,073	,283
Learning - Learning capability	88077,000	276268,000	-,635	,526
Learning - Costs of learning	87424,500	275615,500	-,814	,415

a. Grouping Variable: Industrial Good

Table M-12 – Barrier variable variation due to different types of good

Statistics: Barrier variables of the subgroup of respondents working with industrial goods

	N		Mean	Median	Mode	Std. Deviation
	Valid	Missing				
Technology - Utility	613	0	4,3018	4,5000	4,00	1,35109
Technology - Complexity	613	0	3,3271	3,0000	2,50	1,19754
Technology - Complementarity	613	0	3,3491	3,0000	3,00	1,13313
Technology - Adaptability	613	0	4,1577	4,0000	4,00	1,12304
Social Structure - Social context	613	0	4,0315	4,0000	3,67	1,18684
Social Structure - Orientations	613	0	3,9826	4,0000	3,67	1,08836
Social Structure - Contagion	613	0	3,3556	3,5000	3,50	1,14402
Social Structure - Environmental Awareness	613	0	3,9538	4,0000	3,67	1,06857
Learning - Learning capacity	613	0	3,8869	3,6667	3,67	1,17877
Learning - Learning capability	613	0	3,7868	3,6667	3,33	1,11952
Learning - Costs of learning	613	0	3,2626	3,0000	2,50	1,27457

Table M-13 – General statistics of barrier variables with industrial goods

Statistics: Barrier variables of the subgroup of respondents working with consumer goods

	N		Mean	Median	Mode	Std. Deviation
	Valid	Missing				
Technology - Utility	295	0	4,2763	4,5000	4,00	1,40907
Technology - Complexity	295	0	3,3169	3,0000	2,50	1,34533
Technology - Complementarity	295	0	3,5034	3,5000	3,50	1,17151
Technology - Adaptability	295	0	4,0915	4,0000	4,67	1,21697
Social Structure - Social context	295	0	3,8034	3,6667	3,67	1,15950
Social Structure - Orientations	295	0	4,1367	4,0000	4,00	1,18145
Social Structure - Contagion	295	0	3,4898	3,5000	3,00	1,19305
Social Structure - Environmental Awareness	295	0	3,7932	3,6667	4,00	1,09584
Learning - Learning capacity	295	0	3,7955	3,6667	3,67	1,24630
Learning - Learning capability	295	0	3,8418	3,6667	3,67	1,20147
Learning - Costs of learning	295	0	3,3593	3,0000	3,00	1,33492

Table M-14 – General statistics of barrier variables with consumer goods

Appendix N. Correlation coefficients of survey analysis

Correlations of barrier variables via Spearman's rho

	Spearman's rho										
	Correlation Coefficient										
	Technology - Utility	Technology - Complexity	Technology - Complementarity	Technology - Adaptability	Social Structure - Social context	Social Structure - Orientations	Social Structure - Contagion	Social Structure - Environmental Awareness	Learning - Capacity	Learning - Capability	Learning - Costs of learning
Technology - Utility	1,000	,448**	,447**	,513**	,323**	,463**	,340**	,307**	,388**	,361**	,354**
Technology - Complexity	,448**	1,000	,484**	,446**	,317**	,354**	,307**	,275**	,363**	,355**	,478**
Technology - Complementarity	,447**	,484**	1,000	,434**	,272**	,414**	,365**	,234**	,346**	,333**	,411**
Technology - Adaptability	,513**	,446**	,434**	1,000	,468**	,494**	,339**	,358**	,471**	,435**	,415**
Social Structure - Social context	,323**	,317**	,272**	,468**	1,000	,392**	,370**	,418**	,483**	,471**	,381**
Social Structure - Orientations	,463**	,354**	,414**	,494**	,392**	1,000	,470**	,277**	,547**	,518**	,372**
Social Structure - Contagion	,340**	,307**	,365**	,339**	,370**	,470**	1,000	,244**	,472**	,437**	,346**
Social Structure - Environmental Awareness	,307**	,275**	,234**	,358**	,418**	,277**	,244**	1,000	,388**	,329**	,335**
Learning - Capacity	,388**	,363**	,346**	,471**	,483**	,547**	,472**	,388**	1,000	,626**	,463**
Learning - Capability	,361**	,355**	,333**	,435**	,471**	,518**	,437**	,329**	,626**	1,000	,409**
Learning - Costs of learning	,354**	,478**	,411**	,415**	,381**	,372**	,346**	,335**	,463**	,409**	1,000

**. Correlation is significant at the 0.01 level (2-tailed).

Table N-1 – Correlation of barrier variables via the test of Spearman's rho

Correlations of barrier variables via Kendall's tau_b

	Kendall's tau_b										
	Correlation Coefficient										
	Technology - Utility	Technology - Complexity	Technology - Complementarity	Technology - Adaptability	Social Structure - Social context	Social Structure - Orientations	Social Structure - Contagion	Social Structure - Environmental Awareness	Learning - Capacity	Learning - Capability	Learning - Costs of learning
Technology - Utility	1,000	,346**	,347**	,394**	,241**	,353**	,261**	,230**	,290**	,270**	,270**
Technology - Complexity	,346**	1,000	,379**	,342**	,238**	,268**	,234**	,207**	,276**	,268**	,371**
Technology - Complementarity	,347**	,379**	1,000	,335**	,204**	,314**	,284**	,176**	,260**	,252**	,316**
Technology - Adaptability	,394**	,342**	,335**	1,000	,353**	,373**	,256**	,268**	,354**	,327**	,315**
Social Structure - Social context	,241**	,238**	,204**	,353**	1,000	,291**	,278**	,310**	,366**	,355**	,287**
Social Structure - Orientations	,353**	,268**	,314**	,373**	,291**	1,000	,361**	,202**	,415**	,395**	,280**
Social Structure - Contagion	,261**	,234**	,284**	,256**	,278**	,361**	1,000	,183**	,365**	,335**	,264**
Social Structure - Environmental Awareness	,230**	,207**	,176**	,268**	,310**	,202**	,183**	1,000	,289**	,245**	,252**
Learning - Capacity	,290**	,276**	,260**	,354**	,366**	,415**	,365**	,289**	1,000	,486**	,354**
Learning - Capability	,270**	,268**	,252**	,327**	,355**	,395**	,335**	,245**	,486**	1,000	,309**
Learning - Costs of learning	,270**	,371**	,316**	,315**	,287**	,280**	,264**	,252**	,354**	,309**	1,000

**. Correlation is significant at the 0.01 level (2-tailed).

Table N-2 – Correlation of barrier variables via the test of Kendall's tau

Symmetric Measures: Technology - Utility * Technology - Adaptability

		Value	Asymp. Std. Error[a]	Approx. T[b]	Approx. Sig.
Ordinal by Ordinal	Kendall's tau-b	,394	,022	17,965	,000
	Gamma	,433	,023	17,965	,000
	Spearman Correlation	,513	,027	18,124	,000[c]
Interval by Interval	Pearson's R	,528	,027	18,843	,000[c]
N of Valid Cases		920			

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

c. Based on normal approximation.

Table N-3 – Correlation of adaptability with utility

Symmetric Measures: Technology - Complexity * Technology – Adaptability

		Value	Asymp. Std. Error[a]	Approx. T[b]	Approx. Sig.
Ordinal by Ordinal	Kendall's tau-b	,342	,023	14,731	,000
	Gamma	,378	,025	14,731	,000
	Spearman Correlation	,446	,029	15,085	,000[c]
Interval by Interval	Pearson's R	,466	,028	15,969	,000[c]
N of Valid Cases		920			

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

c. Based on normal approximation.

Table N-4 – Correlation of adaptability with complexity

Symmetric Measures: Technology - Complementarity * Technology – Adaptability

		Value	Asymp. Std. Error[a]	Approx. T[b]	Approx. Sig.
Ordinal by Ordinal	Kendall's tau-b	,335	,023	14,149	,000
	Gamma	,372	,026	14,149	,000
	Spearman Correlation	,434	,030	14,596	,000[c]
Interval by Interval	Pearson's R	,456	,029	15,520	,000[c]
N of Valid Cases		920			

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

c. Based on normal approximation.

Table N-5 – Correlation of adaptability with complementarity

Symmetric Measures: Social Structure – Social context * Social Structure – Environmental Awareness

		Value	Asymp. Std. Error[a]	Approx. T[b]	Approx. Sig.
Ordinal by Ordinal	Kendall's tau-b	,310	,022	14,031	,000
	Gamma	,338	,024	14,031	,000
	Spearman Correlation	,418	,029	13,922	,000[c]
Interval by Interval	Pearson's R	,426	,029	14,283	,000[c]
N of Valid Cases		920			

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

c. Based on normal approximation.

Table N-6 – Correlation of environmental awareness with context

Symmetric Measures: Social Structure - Orientations * Social Structure – Environmental Awareness

		Value	Asymp. Std. Error[a]	Approx. T[b]	Approx. Sig.
Ordinal by Ordinal	Kendall's tau-b	,202	,024	8,544	,000
	Gamma	,220	,026	8,544	,000
	Spearman Correlation	,277	,031	8,730	,000[c]
Interval by Interval	Pearson's R	,288	,031	9,096	,000[c]
N of Valid Cases		920			

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

c. Based on normal approximation.

Table N-7 – Correlation of environmental awareness with orientations

Symmetric Measures: Social Structure - Contagion * Social Structure – Environmental Awareness

		Value	Asymp. Std. Error[a]	Approx. T[b]	Approx. Sig.
Ordinal by Ordinal	Kendall's tau-b	,183	,025	7,418	,000
	Gamma	,205	,027	7,418	,000
	Spearman Correlation	,244	,032	7,615	,000[c]
Interval by Interval	Pearson's R	,243	,035	7,606	,000[c]
N of Valid Cases		920			

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

c. Based on normal approximation.

Table N-8 – Correlation of environmental awareness with contagion

Symmetric Measures: Technology - Utility * Social Structure – Environmental Awareness

		Value	Asymp. Std. Error[a]	Approx. T[b]	Approx. Sig.
Ordinal by Ordinal	Kendall's tau-b	,230	,024	9,497	,000
	Gamma	,254	,027	9,497	,000
	Spearman Correlation	,307	,032	9,781	,000[c]
Interval by Interval	Pearson's R	,318	,033	10,149	,000[c]
N of Valid Cases		920			

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

c. Based on normal approximation.

Table N-9 – Correlation of environmental awareness with utility

Symmetric Measures: Technology - Complexity * Social Structure – Environmental Awareness

		Value	Asymp. Std. Error[a]	Approx. T[b]	Approx. Sig.
Ordinal by Ordinal	Kendall's tau-b	,207	,025	8,408	,000
	Gamma	,230	,027	8,408	,000
	Spearman Correlation	,275	,032	8,666	,000[c]
Interval by Interval	Pearson's R	,276	,033	8,710	,000[c]
N of Valid Cases		920			

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

c. Based on normal approximation.

Table N-10 – Correlation of environmental awareness with complexity

Symmetric Measures: Technology - Complementarity * Social Structure – Environmental Awareness

		Value	Asymp. Std. Error[a]	Approx. T[b]	Approx. Sig.
Ordinal by Ordinal	Kendall's tau-b	,176	,024	7,157	,000
	Gamma	,196	,027	7,157	,000
	Spearman Correlation	,234	,032	7,294	,000[c]
Interval by Interval	Pearson's R	,261	,034	8,189	,000[c]
N of Valid Cases		920			

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

c. Based on normal approximation.

Table N-11 – Correlation of environmental awareness with complementarity

Appendix O. Reliability analysis as part of survey analysis

Item-Total Statistics of the model

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Squared Multiple Correlation	Cronbach's Alpha if Item Deleted
Utility perceived to be less than o.T.	73,91	286,262	,545	,389	,874
n.T. fails to exceed measurable specifications of o.T.	74,08	292,461	,409	,261	,878
Complexity focuses attention on overall effectiveness	74,60	285,218	,585	,423	,873
Complex radically n.T. cannot be introduced frequently	75,34	298,727	,339	,276	,880
Complementarity of o.T. results in higher total utility	74,91	294,861	,477	,303	,876
No dominant design within an industry compared to o.T.	74,88	294,645	,432	,340	,877
Individuals face difficulties in accessing n.T.	74,60	284,730	,597	,417	,872
Access is granted to small social groups	74,52	300,217	,309	,193	,881
Access is restricted by external institutions (e.g. government)	73,89	292,162	,406	,255	,878
Personal orientations towards its use are negative.	73,97	290,257	,520	,406	,875
Community of users is towards o.T.	74,62	289,795	,502	,357	,875
Contagion not strong enough to displace community norms.	74,67	292,527	,488	,346	,876
Poor execution of marketing	75,13	296,361	,375	,204	,879
Limited individual learning capacity or ability	74,11	287,736	,533	,421	,874
Not enough resource to access training	74,67	288,898	,554	,427	,874
Not sufficient resources & guidance for learning n.T.	74,53	285,762	,564	,421	,873
Way of using very different compared to o.T.	74,45	294,156	,399	,228	,878
No community expert group created for n.T.	74,33	288,128	,494	,343	,875
No possibilities for experiencing n.T. in industry	74,69	287,914	,533	,353	,874
High switching costs and learning efforts	75,38	289,726	,529	,323	,874
Learning efforts within industry are expensive.	74,62	289,569	,481	,294	,876

Table O-1 – Item total statistics with items originating from the LF-model

Reliability Statistics of the model

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
,881	,882	21

Reliability Statistics of the model

w/ alternative item of community orientation towards an even newer technology

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
,874	,874	21

Reliability Statistics of the model

w/ industrial cooperation as additional item

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
,884	,885	22

Reliability Statistics of the model

w/ adaptability as additional scale operationalised by three items

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
,894	,895	24

Reliability Statistics of the model

w/ environmental awareness as additional scale operationalised by three items

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
,885	,885	24

Table O-2 – Internal consistency of the model with different modifications

Reliability Statistics of technology conditions

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
,734	,735	6

Reliability Statistics of technology conditions

w/ adaptability as additional scale operationalised by three items

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
,790	,791	9

Reliability Statistics of social structure conditions

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
,695	,696	7

Reliability Statistics of social structure conditions

w/ alternative item of community orientation towards an even newer technology

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
,660	,658	7

Reliability Statistics of social structure conditions

w/ industrial cooperation as additional item

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
,722	,723	8

Reliability Statistics of social structure conditions

w/ environmental awareness as additional scale operationalised by three items

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
,732	,732	10

Reliability Statistics of social structure conditions w/ industry cooperation & environmental awareness as additional scales each operationalised by three items

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
,755	,754	12

Reliability Statistics of learning conditions

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
,785	,787	8

Table O-3 – Reliability statistics of the model conditions with different modifications

Appendix P. Survey results supporting case study research

Statistics of Likert-type items for barriers perceived by media production & distribution experts

	N		Mean	Median	Mode
	Valid	Missing			
Utility perceived to be less than o.T.	26	0	4,23	4,00	6
~~n.T. fails to exceed measurable specifications of o.T.~~	~~26~~	~~0~~	~~4,46~~	~~5,00~~	~~5~~
Complexity focuses attention on overall effectiveness	26	0	3,15	3,00	3
Complex radically n.T. cannot be introduced frequently	26	0	2,85	2,50	2
Complementarity of o.T. results in higher total utility	26	0	3,00	3,00	3
No dominant design within an industry compared to o.T.	26	0	3,58	3,00	3
~~Not adaptable and not perceived to be future-ready~~	~~26~~	~~0~~	~~3,58~~	~~3,00~~	~~3~~
~~n.T. not adaptable to community needs~~	~~26~~	~~0~~	~~4,50~~	~~4,50~~	~~6~~
~~Cannot be adapted to other industries~~	~~26~~	~~0~~	~~3,69~~	~~3,50~~	~~3~~
~~Individuals face difficulties in accessing n.T.~~	~~26~~	~~0~~	~~3,38~~	~~3,00~~	~~3~~
~~Access is granted to small social groups~~	~~26~~	~~0~~	~~4,04~~	~~4,00~~	~~3~~
Access is restricted by external institutions (e.g. government)	26	0	4,69	5,50	6
~~Personal orientations towards its use are negative.~~	~~26~~	~~0~~	~~4,46~~	~~5,00~~	~~5~~
~~Community of users is towards o.T.~~	~~26~~	~~0~~	~~3,42~~	~~3,00~~	~~3~~
Community discussions about an even better T.	26	0	3,65	4,00	4
Missing industry collaboration	26	0	3,73	4,00	2
Contagion not strong enough to displace community norms.	26	0	3,69	4,00	2[a]
Poor execution of marketing	26	0	3,50	3,00	2
~~Not perceived as more environmentally friendly than o.T.~~	~~26~~	~~0~~	~~3,85~~	~~4,00~~	~~4~~
~~Sustainability aspects of n.T. not explained to community~~	~~26~~	~~0~~	~~4,15~~	~~4,00~~	~~4~~
~~Marketing exaggerates environmentally friendliness~~	~~26~~	~~0~~	~~3,15~~	~~3,00~~	~~3~~
~~Limited individual learning capacity or ability~~	~~26~~	~~0~~	~~4,04~~	~~4,00~~	~~3~~
~~Not enough resource to access training~~	~~26~~	~~0~~	~~3,85~~	~~4,00~~	~~5~~
~~Not sufficient resources & guidance for learning n.T.~~	~~26~~	~~0~~	~~3,27~~	~~3,00~~	~~2~~
~~Way of using very different compared to o.T.~~	~~26~~	~~0~~	~~3,62~~	~~3,50~~	~~2~~
~~No community expert group created for n.T.~~	~~26~~	~~0~~	~~4,35~~	~~4,00~~	~~6~~
~~No possibilities for experiencing n.T. in industry~~	~~26~~	~~0~~	~~3,27~~	~~3,00~~	~~2~~
~~High switching costs and learning efforts~~	~~26~~	~~0~~	~~2,54~~	~~2,00~~	~~2~~
~~Learning efforts within industry are expensive.~~	~~26~~	~~0~~	~~3,58~~	~~3,00~~	~~3~~

a. Multiple modes exist. The smallest value is shown

Table P-1 – General statistics of barrier items of media production industry

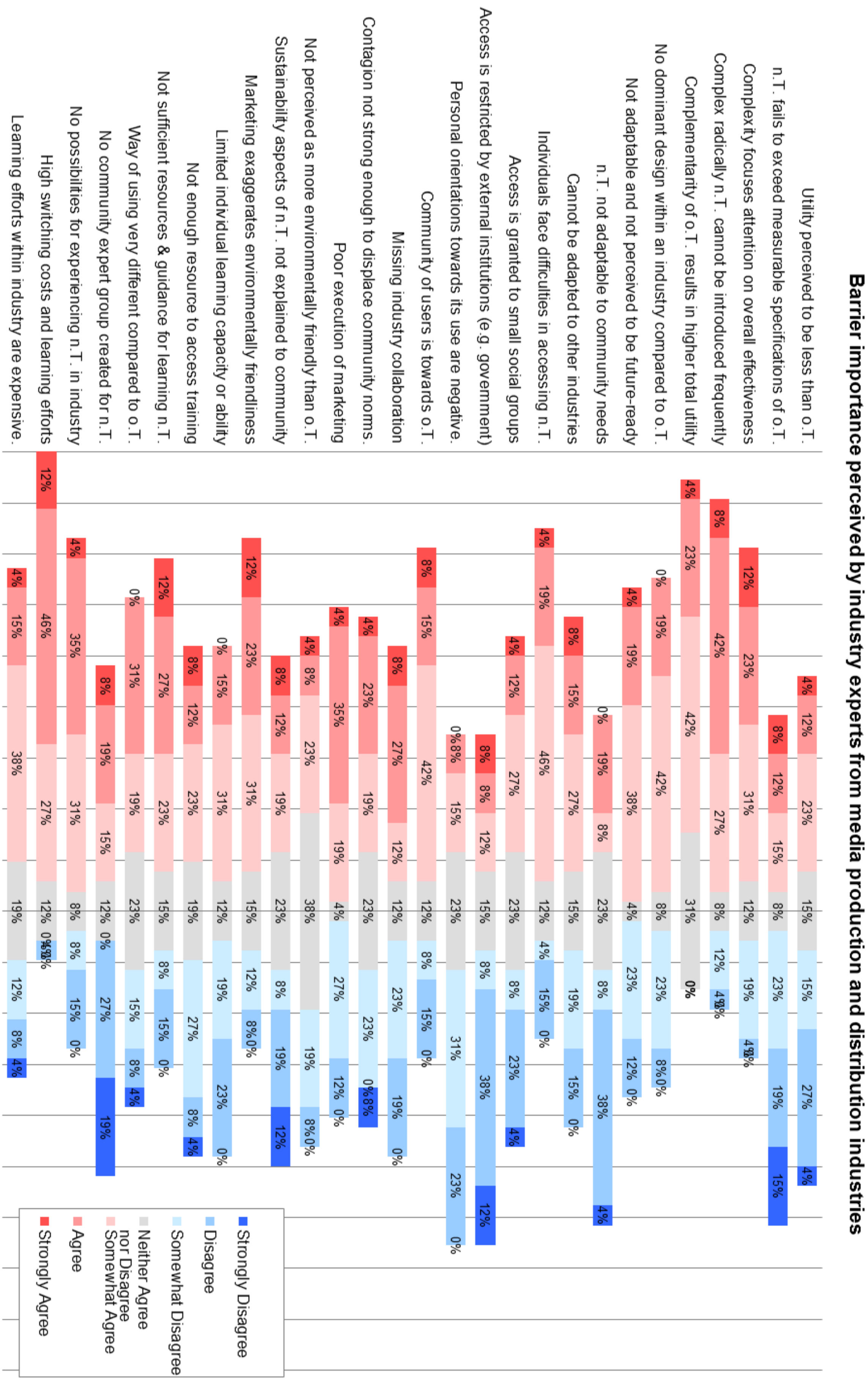

Figure P-1 – Agreement frequencies for barrier items in media production

Appendix Q. Barrier framework and weighting schemes

Authors	Peattie & Crane (2005)	*Wolfe (1994)*	*Rogers (1995)*	*Petkova et al. (2010)*	Cronin et al. (2011)	Steinheber & Chlupsa (2012)	Berman & McLaughlin (1977)	Steinheber (2014)
Domain	Market/Industry	Community and Individuals	Community, Individuals, Market/ Industry	Community	Market/ Industry	Individuals	Community and Individuals	Community and Market/ Industry
Conditions	Technology, Social Structure	Technology, Social structure, Learning	Technology, Social structure, Learning	Technology (Adaptability)	Social Structure (Environmental Awareness)	Social Structure and Technologies	Technology (Adaptability)	Social Structure (Context / Orientation)
Objectives	Examination of “green marketing” since the early 1990s and provision of a profound critique of both theory and practice. .	Organizational innovation, and review and critic of existing innovation research	Researching diffusion of innovation, influencing factors and	Barriers to innovation in the field of medical devices	Research of green marketing strategies: regarding the different opportunities of important stakeholders. Outlining further research areas.	Media technology use among representatives of the generation z and their perception of contemporary technology	Success factors and reasons of adopting innovation in projects of the educational environment.	Barriers for digital radio technology as technology substitution for FM in Central Europe (Germany)
Method	Theoretical	Theoretical	Theoretical based on prior empirics	Theoretical, Empirical	Theoretical	Theoretical / empirical	Empirical	Theoretical/ empirical case study research
Result	Misconceived green marketing as green-spinning/selling/ harvesting, enviropreneur & compliance marketing.	Inconsistency of innovation research, such as innovation characteristic; suggestion of six attributes (e.g. adaptability &radicalness)	Re-invention / adaptability as further innovation attribute mentioned with additional need of individual learning.	Many elements necessary for diffusion of new devices miss in low-resource countries, such as adaptability to community needs.	Different results, e.g. green marketing can be a facilitating but if applied in the wright way depending on the industry	Strong need for internet connectivity and flexibility of products among young consumers	Only a few innovations were adopted to be used regularly in education. Missing adaptability mentioned as barrier.	Diversity of barriers as reasons for non-adoption, e.g. a missing orientation for inter-industrial collaboration
Specific mention of technology non-use	Yes	No	No	Yes	No	No	Yes	Yes

Table Q-1 – Further literature theoretically supporting the revised LF-model

New technology fails to **replace older** (or no use of) technology when …			In the domain of the:		
			Individual User	Community of Users	Market / Industry
Given the effect of conditions relating to:	Technology	utility …	… is perceived to be less than the older technology *(Zeithaml, 1988; Davis, 1989; Moore & Benbasat, 1991)*		… fails to exceed the older technology's measurable specifications *(Roure & Keeley, 1990)*
		complexity …	… focuses attention on overall effectiveness not newest feature *(Maidique & Zirger, 1984; Moreau et al., 2001)*		… renders really new innovation less frequent *(Song & Montoya-Weiss, 1998)*
		Complementarity …	… of older technology results in higher total utility *(Shy, 2001)*		… does not lead to a dominant design *(Abernathy & Utterback, 1978)*
	Social Structure	context …	… creates material limits to access *(Krieg, 1995; Kling, 1999; Selwyn, 2003)*	… supports social divisions to access (Chatman, 1996)	… restricts access on behalf of proprietors / the state (*Taylor et al., 2003; Hall & Khan, 2003)*
		orientations …	… towards its use are negative *(Bruland, 1995; Kingsley & Anderson, 1998; Morris & Venkatesh, 2000)*	… are towards the older technology (Brown & Duguid, 1991; Rogers, 1962; Wenger, 1998)	… of one industry is not supporting inter-industrial collaboration to develop the market *(Margolis & Zuboy, 2006; Steinheber, 2014)*
		contagion …	… is not strong enough to displace existing community norms *(Richins & Bloch, 1986; Burt, 1987; Bruland, 1995)*		… is not dispersed due to poor marketing and/or operations functionality *(Stuart & Abetti, 1987; Calantone et al., 1993; Easingwood & Koustelos, 2000)*
	Learning	capacity …	… or cognitive ability limits learning *(Richins & Bloch, 1986; Burt, 1987; Bruland, 1995)*	… to access education is limited *(Miller, 1994)*	… of resources / guidance is inadequate *(Hänninen & Sandberg, 2006)*
		capability …	… generated by older product use does not assist in new technology use *(Cohen & Levinthal, 1990; Ellen et al., 1991)*	… of users has not created a community of expertise *(Aggarwal et al., 1998; Maryse & Eelko,* 2008)	… to experience the product is diminished *(Alba & Hutchinson, 1987)*
		costs …	… related to switching are high *(Shapiro & Varian, 1998; Moreau et al., 2001)*		… of learning determined by the product are prohibitive *(Fornell, 1992)*

Note: A technology's adaptability and the environmental awareness of the social structure are additional aspects for innovation diffusion

Source: Based on MacVaugh and Schiavone (2010)

Table Q-2 – Resulting modification of LF-model by MacVaugh and Schiavone

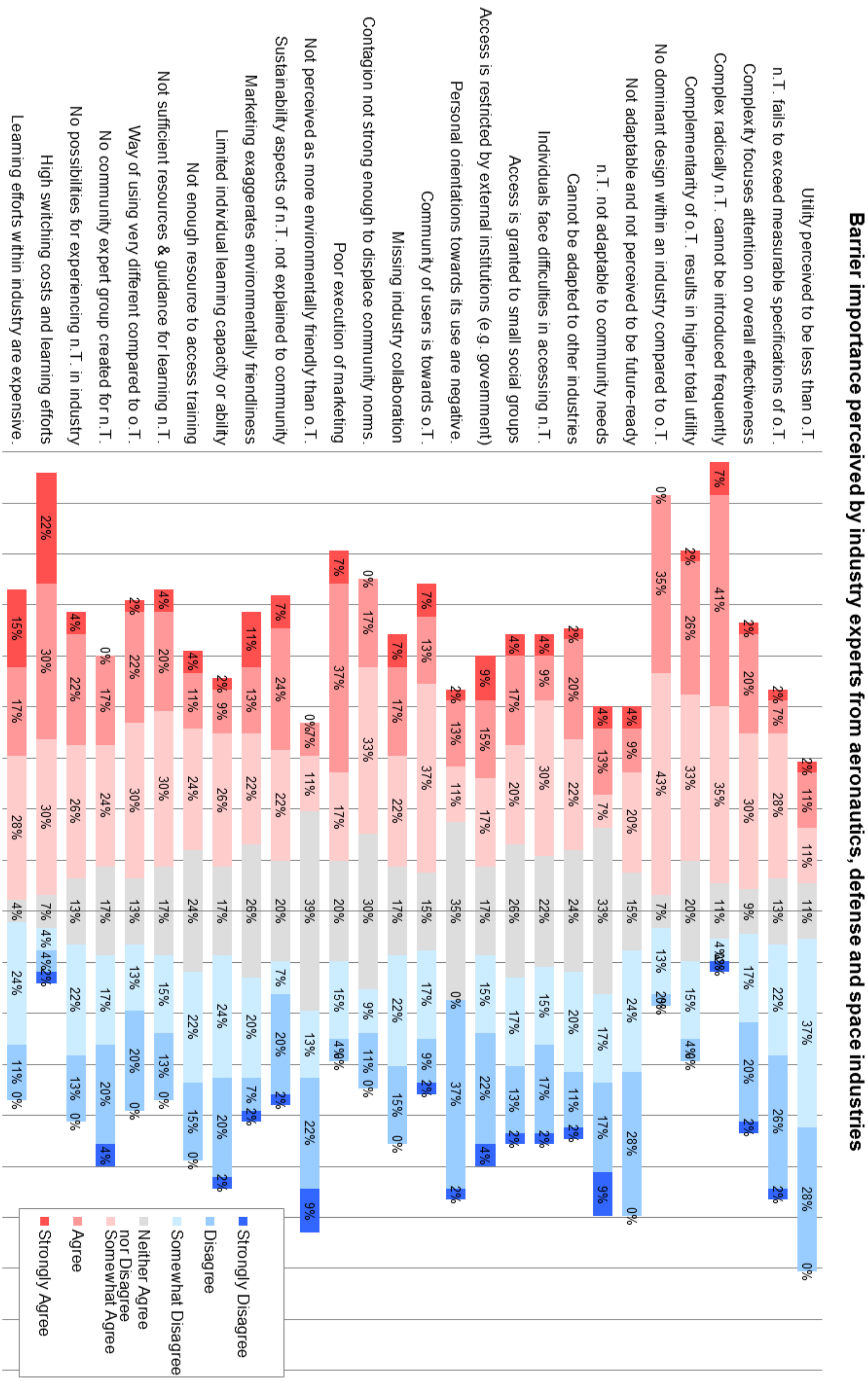

Figure Q-1 – Weighting scheme to assist barrier evaluation in aeronautics

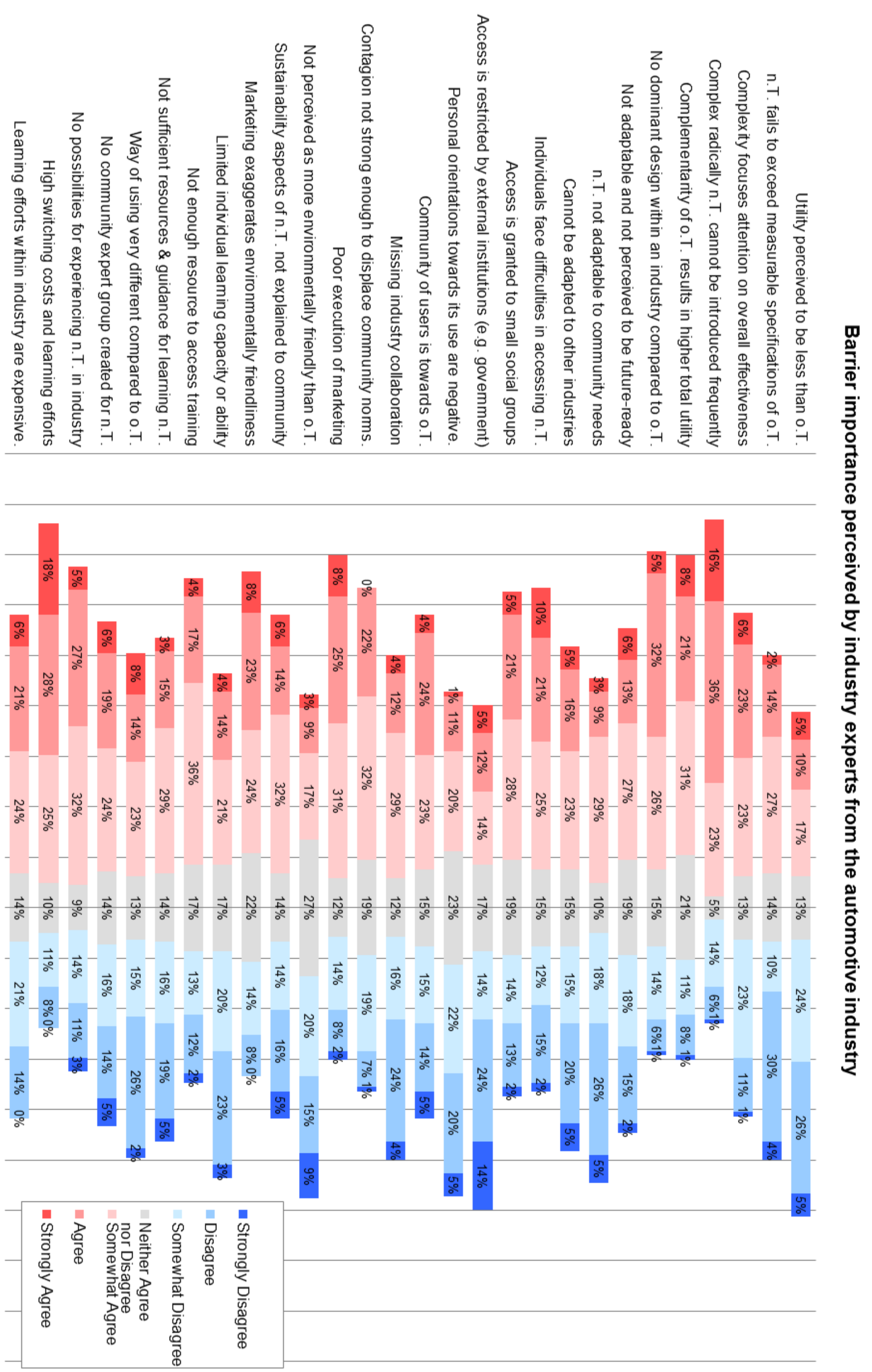

Figure Q-2 – Weighting scheme to assist barrier evaluation in automotive

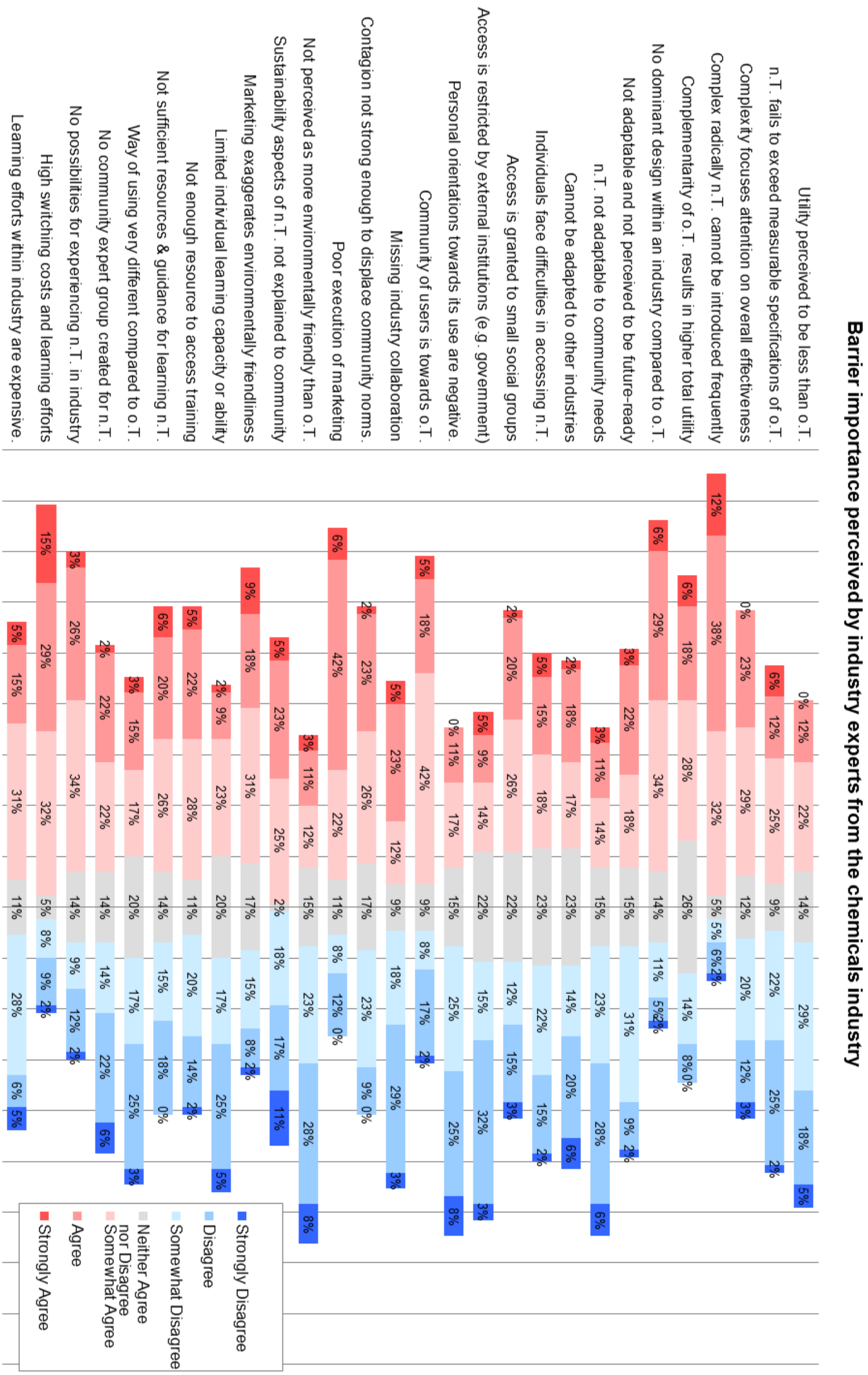

Figure Q-3 – Weighting scheme to assist barrier evaluation in chemical industry

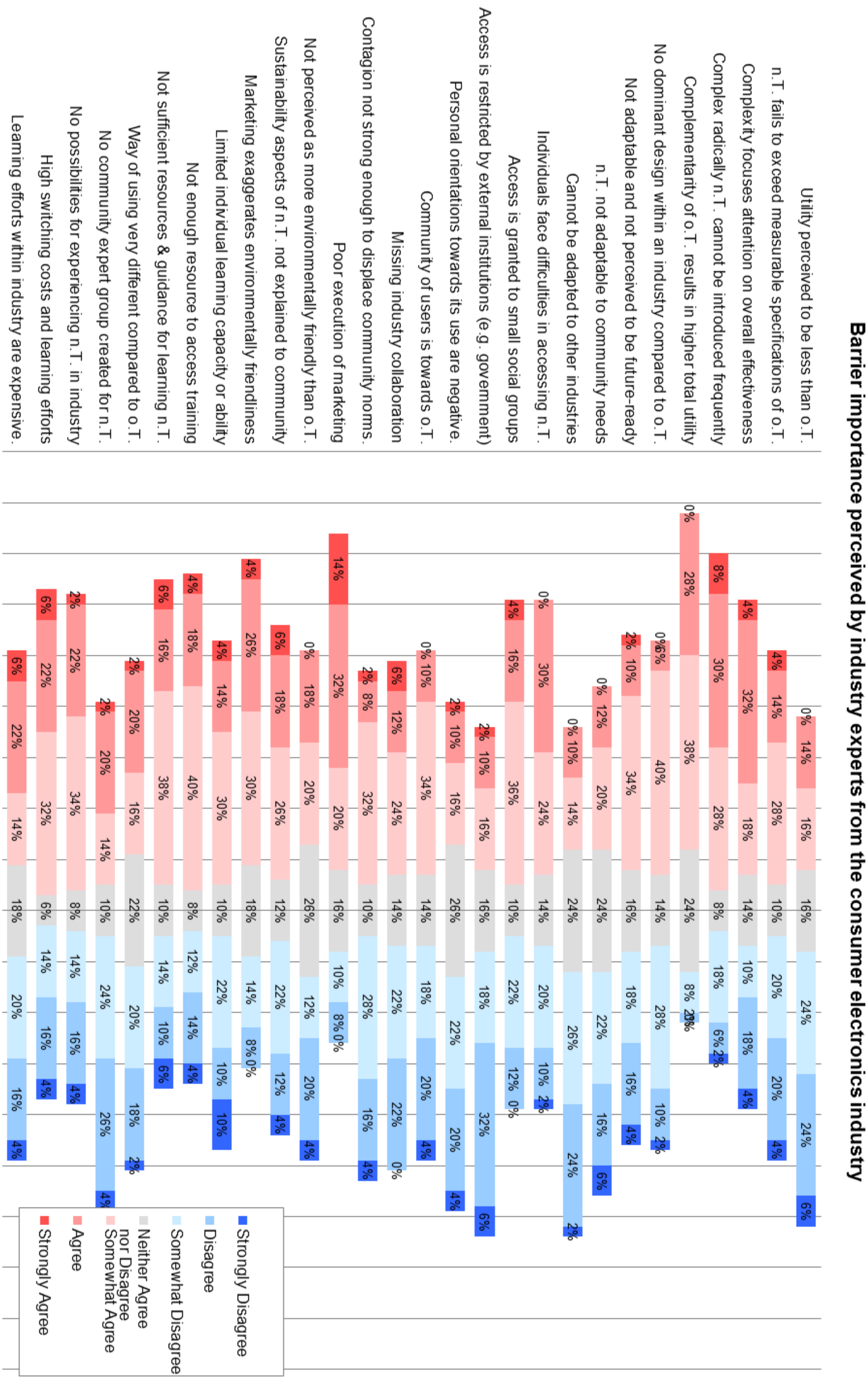

Figure Q-4 – Weighting scheme to assist barrier evaluation in consumer electronics

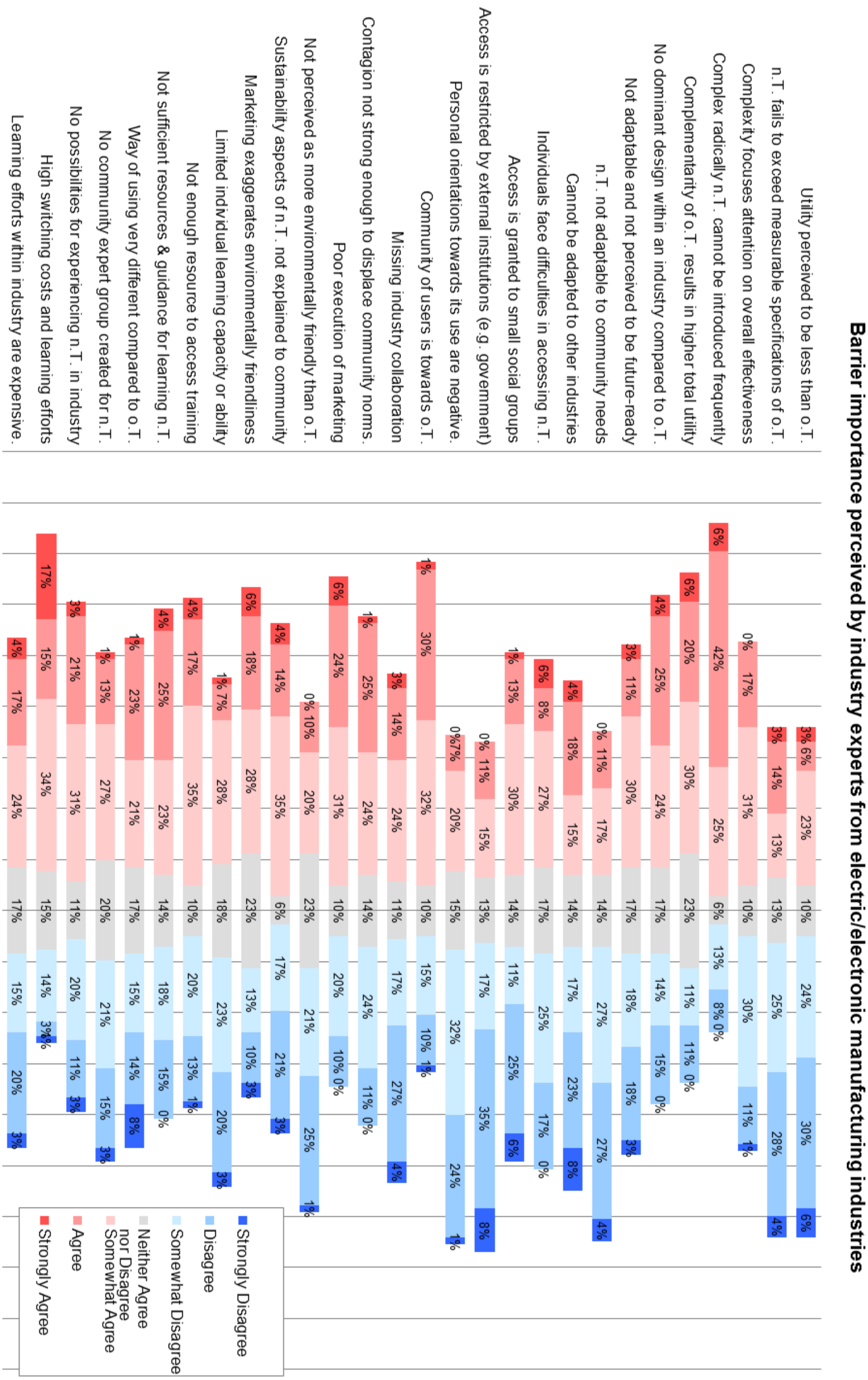

Figure Q-5 – Weighting scheme to assist barrier evaluation in electr. manufacturing

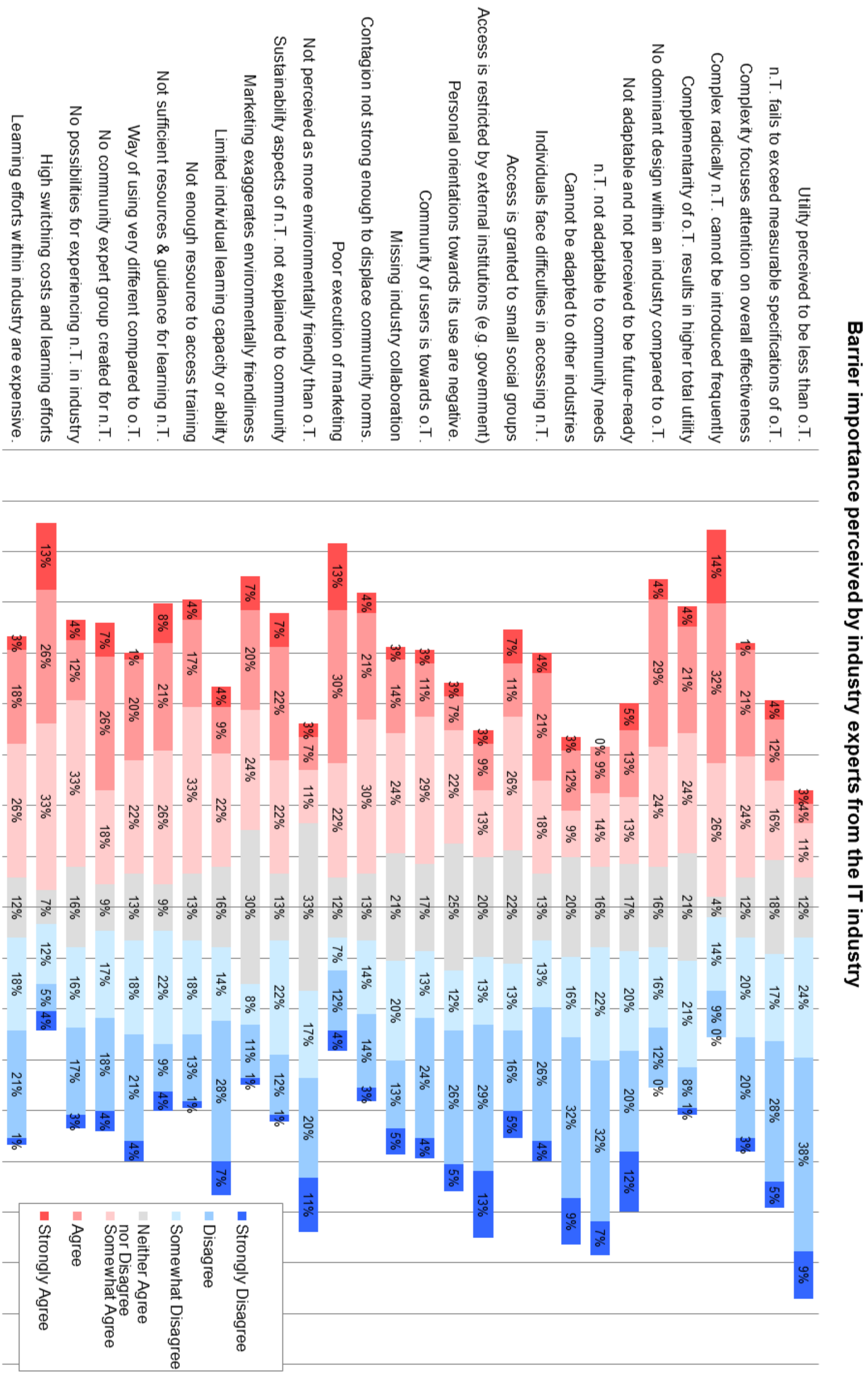

Figure Q-6 – Weighting scheme to assist evaluation usage in IT industries

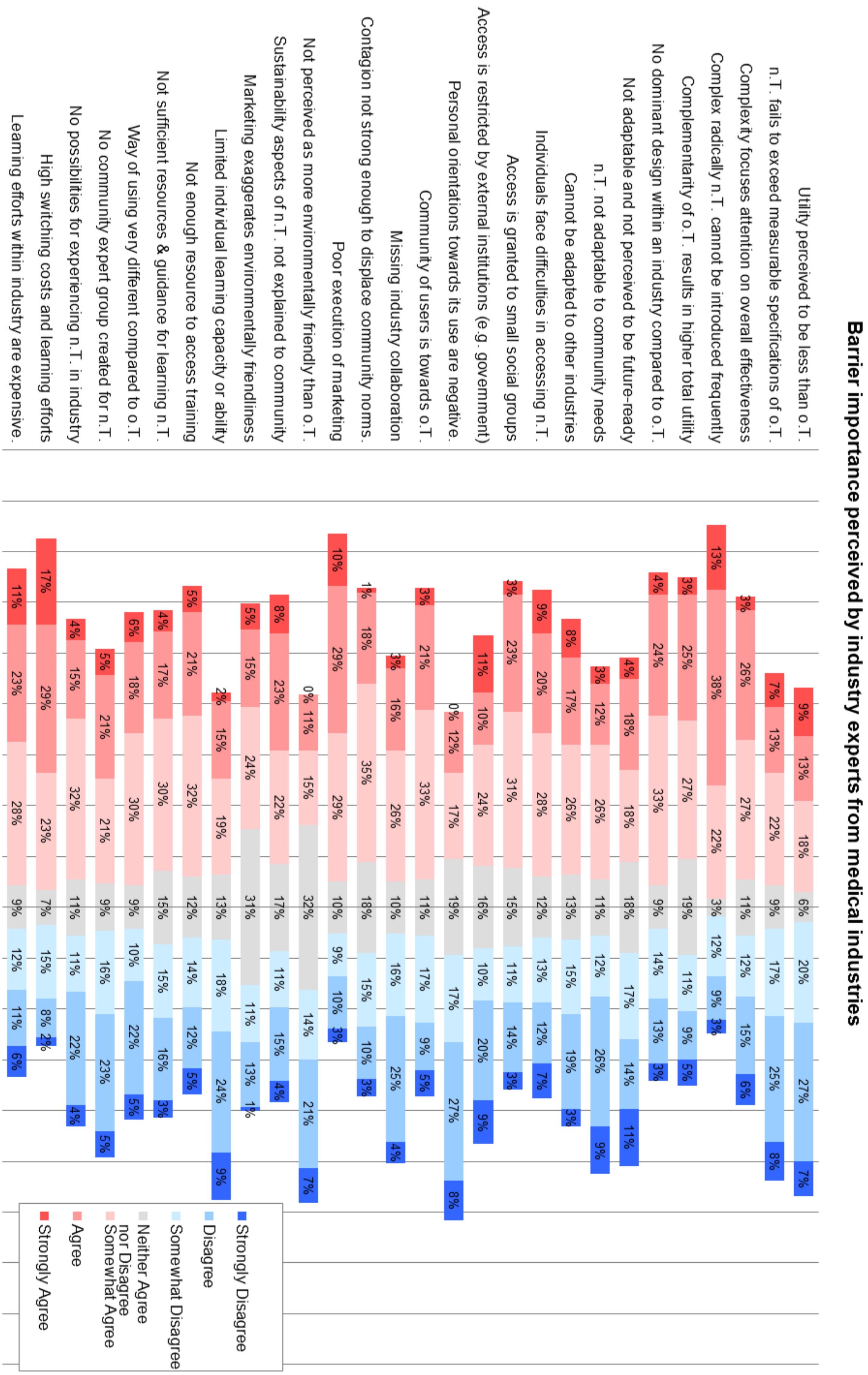

Figure Q-7 – Weighting scheme to assist barrier evaluation in medical industries

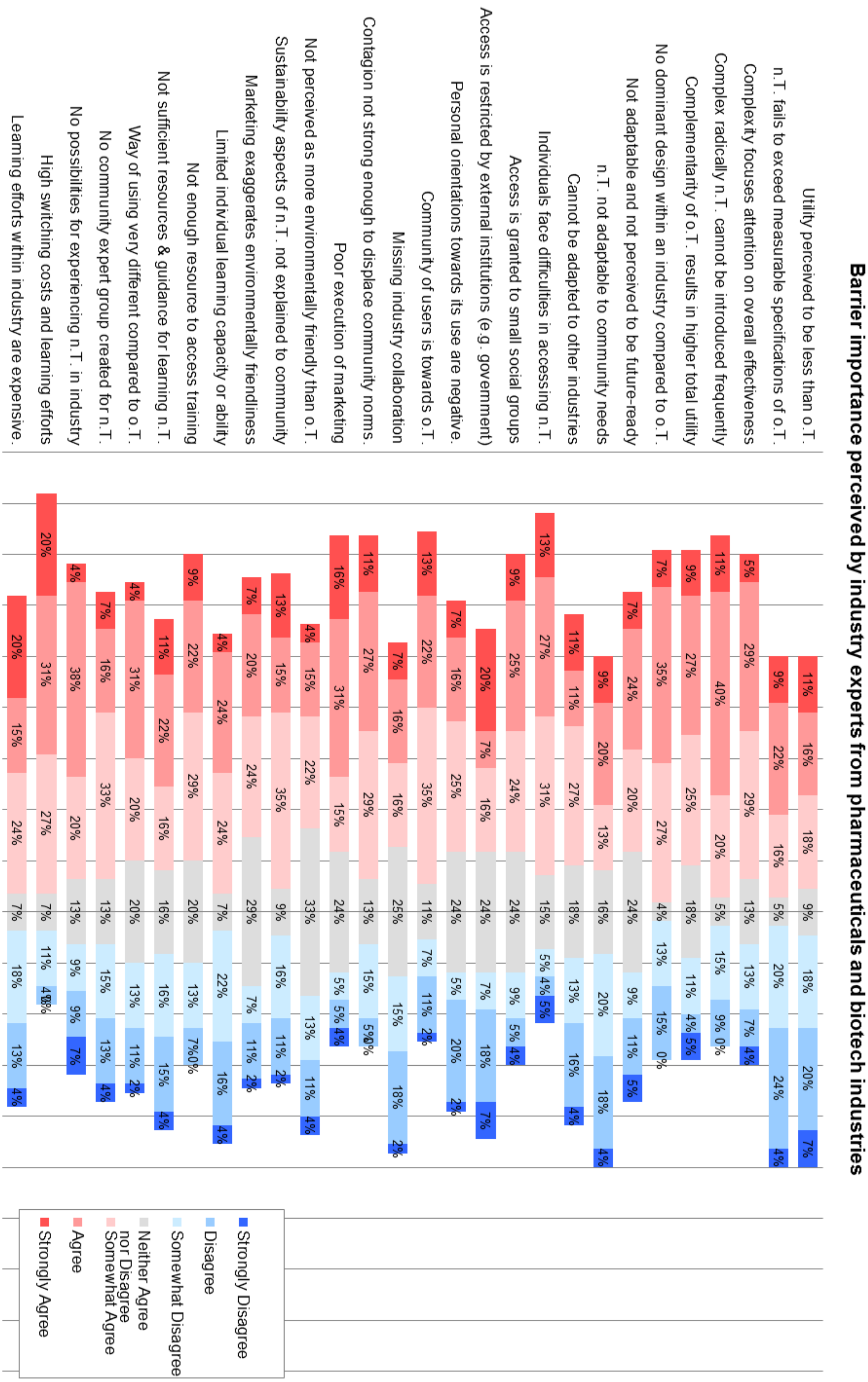

Figure Q-8 – Weighting scheme to assist barrier evaluation in pharma and biotech

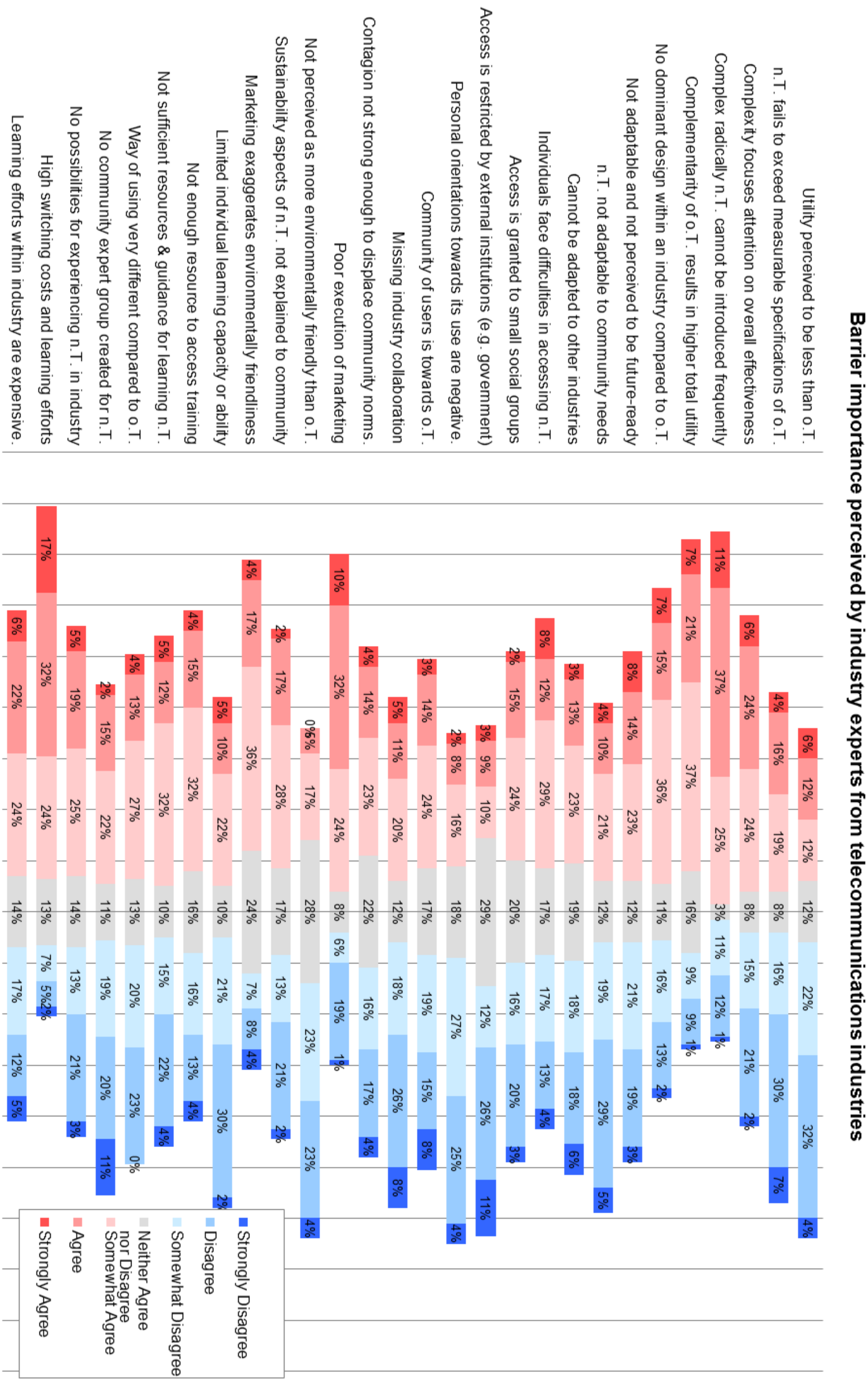

Figure Q-9 – Weighting scheme to assist barrier evaluation in telecommunication

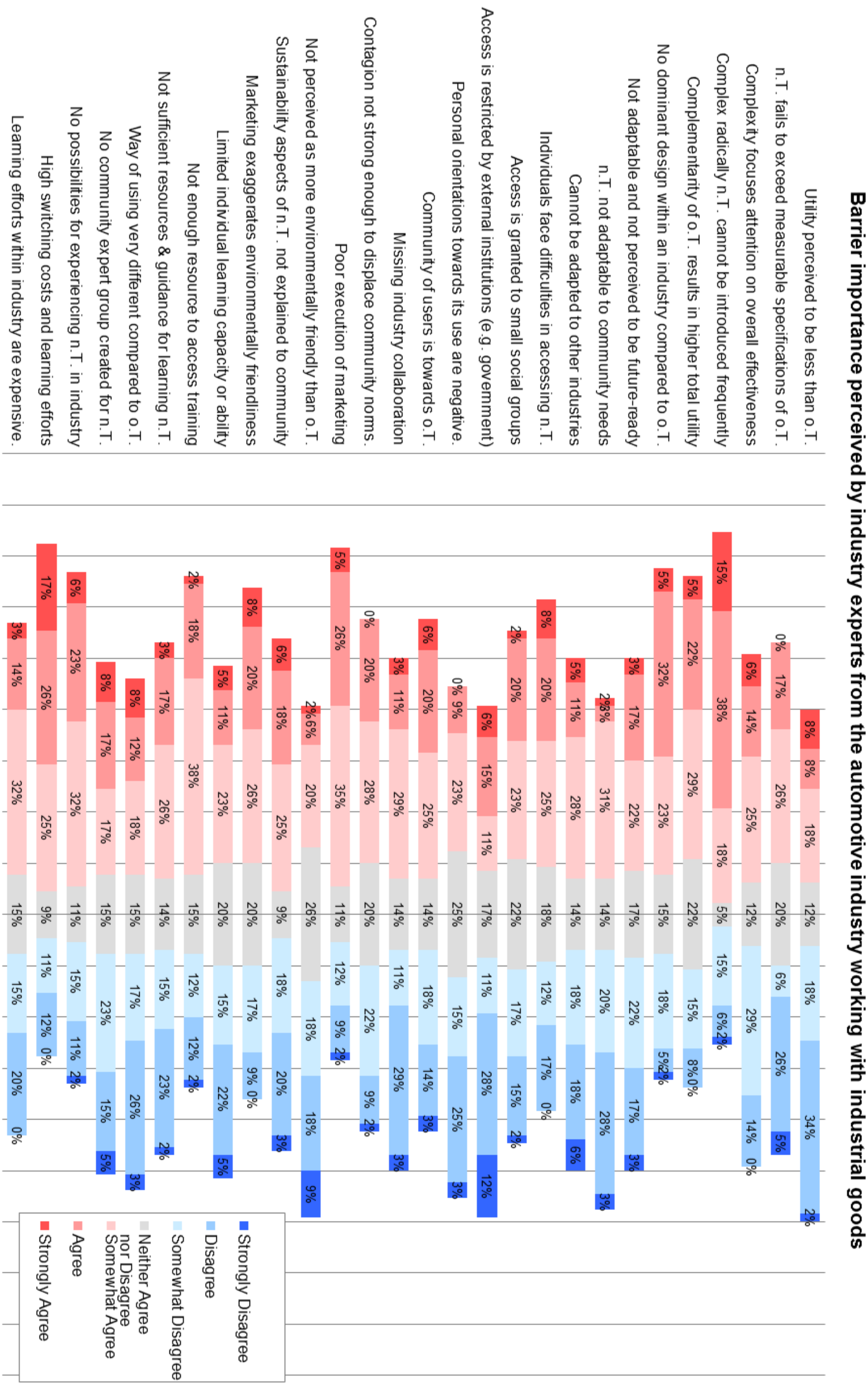

Figure Q-10 – Weighting scheme to assist barrier evaluation in automotive (B2B)

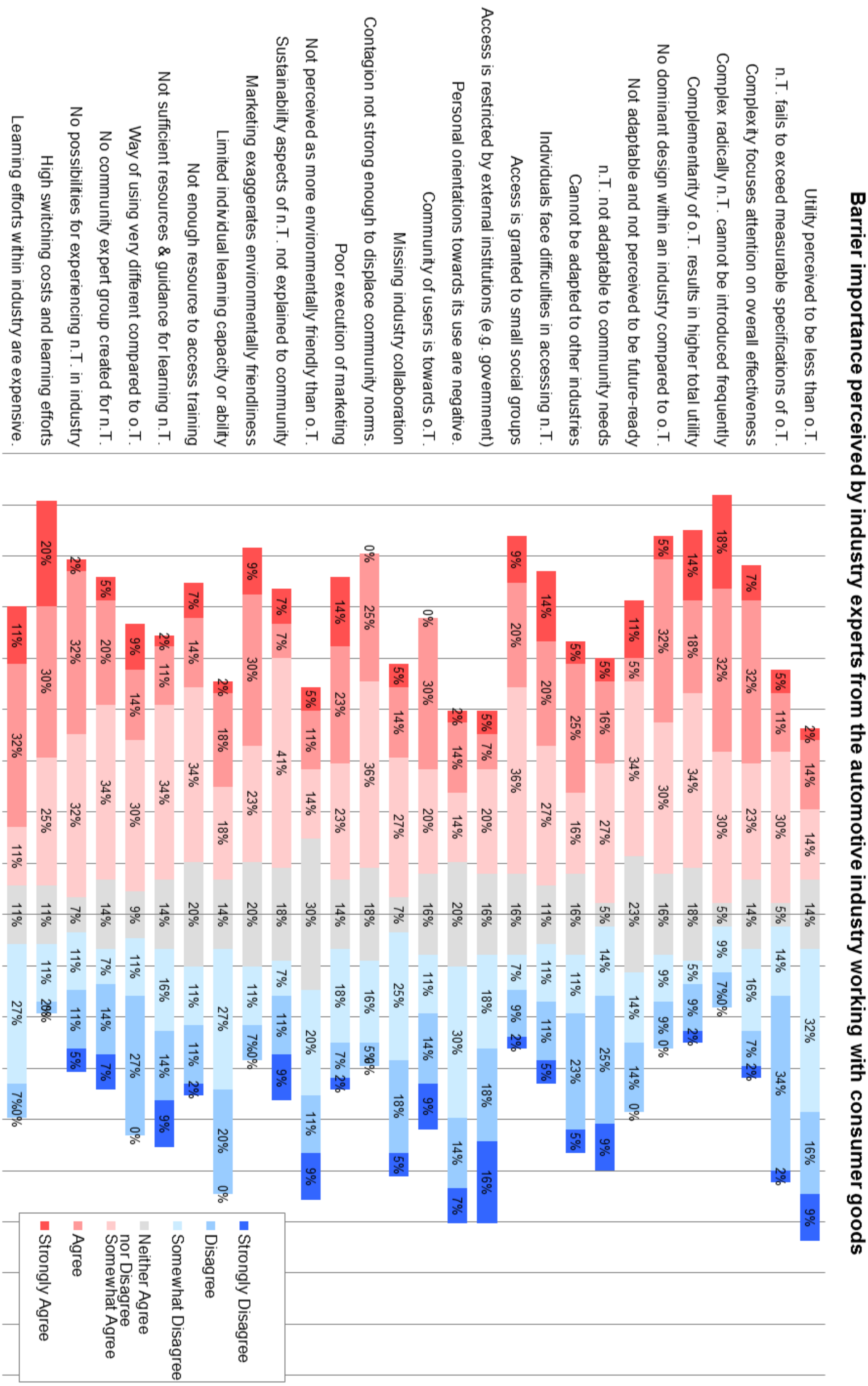

Figure Q-11 – Weighting scheme to assist barrier evaluation in automotive (B2C)

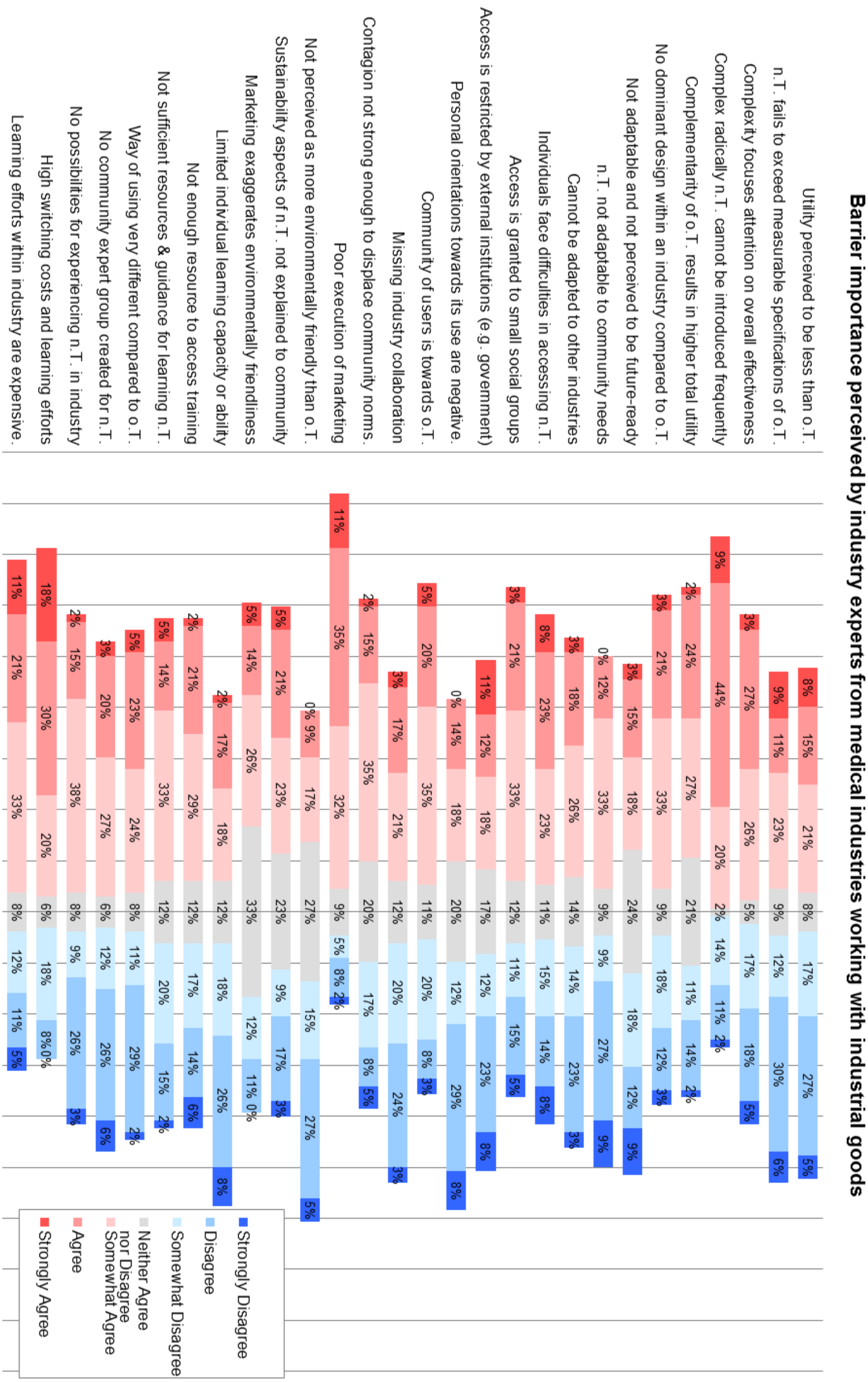

Figure Q-12 – Weighting scheme to assist barrier evaluation in medicals (B2B)

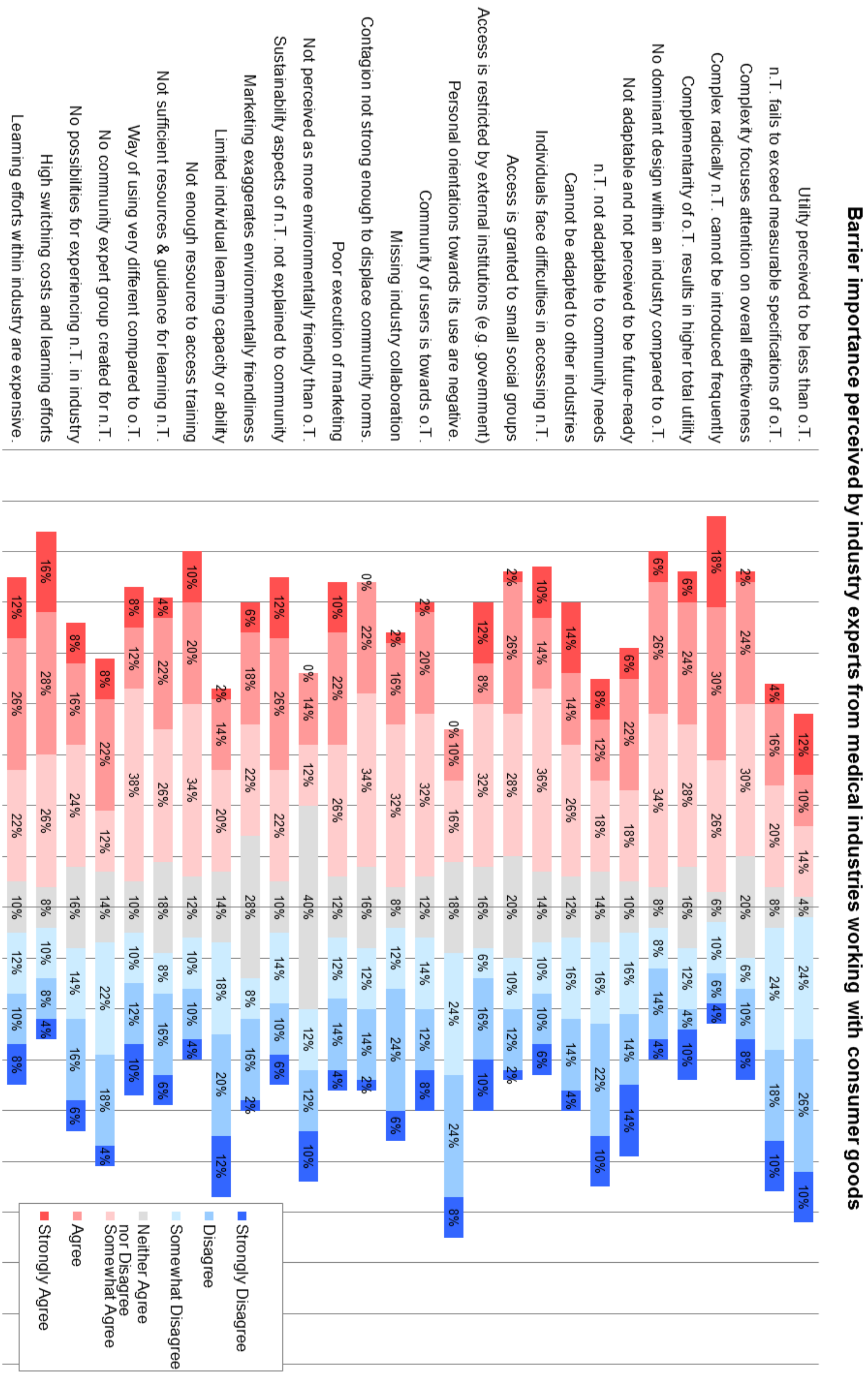

Figure Q-13 – Weighting scheme to assist barrier evaluation in medicals (B2C)

Appendix R. Published papers & conference presentations

Academic conferences and papers

'Crossing the chasm with technologies not contributing to a proper technology mix?', In: Proceedings of the PhD-Symposium for Applied Sciences 2011. Munich, Munich University of Applied Science.

'The perceptions on generation Z on current and future media use', In: Proceedings of Annual Plymouth Business School Postgraduate Symposium 2012. Plymouth, University of Plymouth.

'The perceptions on generation Z on current and future media use', In: Proceedings of Annual Plymouth Business School Postgraduate Symposium 2012. Plymouth, University of Plymouth.

‘Digital radio - The fight for diffusion in Germany’, *Info: The journal of policy, regulation and strategy for telecommunications, information and media*, 2014, 16(5).

'Research methodology - Diffusion of Innovation in emergent and advanced economies', In: Proceedings of the PhD-Symposium for Applied Sciences 2014. Munich, Munich University of Applied Science.

Conference papers

'Weighted Carbon Footprint for Broadcasting Products', In: Proceedings of NAB Broadcast Engineering Conference, Las Vegas, April 2012. Washington, NAB Office of Science, pp. 257-267.

'Sustainability Aspects of Innovative Products in Broadcasting', In: Proceedings of NAB Broadcast Engineering Conference, Las Vegas, April 2012. Washington, NAB Office of Science, pp. 300-308.

'Digital future of sound broadcasting in VHF - lessons learnt from Central Europe', In: Proceedings of NAB Broadcast Engineering Conference, Las Vegas, April 2014. Washington, NAB Office of Science, pp. 88-97.

Conference presentations

‘True Efficiency - New technologies for reduced energy consumption and infrastructure costs’, Conference presentation at ABU 2012, Kuala Lumpur.

‘Solución y eficiencia en sistemas de transmisión sustenables’, Conference presentation at CAPER 2011, Buenos Aires, Argentina, 2011.

‘Difusão da inovação em economias emergentes e avançadas: contrastando fatores de sucesso no Brasil e Alemanha’, Conference presentation at PGT Seminarios 2014, São Paulo.

Research poster used for conference presentations

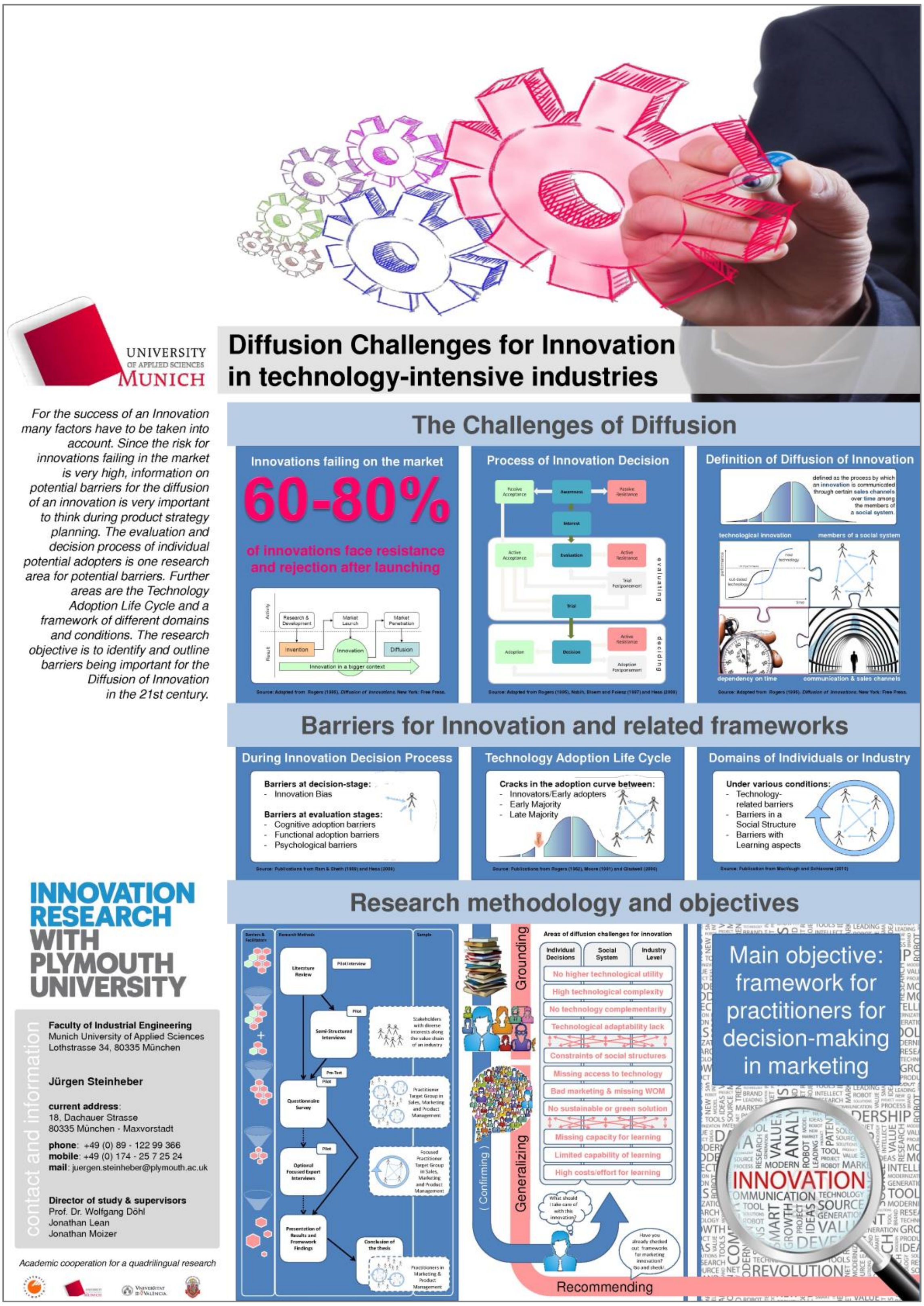

Figure R-1 – Poster illustration for presenting the research area

Research project in an international academic context

Figure R-2 – Published logo representing the transatlantic research collaboration

Contribution as science project to transatlantic cooperation

2013–2014
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Quando ideias se encontram

Figure R-3 – Research project as science contribution to the German-Brazilian year