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service on the road

Implementing a technology roadmapping process in the service industry

The case of a contracted out governmental service

Master thesis
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UNIVERSITEIT TWENTE.

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Colophon

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service on the road

“All you need is the plan, the road map, and the courage to press on to your destination.”

- Earl Nightingale

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Management summary

Introduction

Technology roadmapping has proven to be a useful method for enhancing the effectiveness of technology management. The method aims at identifying key market trends, determining the evolution of products or services and to recognize technological opportunities. The main advantage is that direct linkages among these aspects are created. After the identification of the key market trends it is determined how one should react upon these trends with products or services. Subsequently, technological opportunities are sought for which enable or create these products or services. Thereby an idea is obtained regarding the most promising services or products and technologies for the future.

Although the method has been widely spread within the manufacturing industry, its presence within the service industry is only in its infancy. Scholars advocate that technology roadmaps have to be customized according to the characteristics and context of a firm in order to obtain maximum benefit of the method. This means that technology roadmaps are highly context dependent and its transferability to other contexts is questioned. Research that tests the applicability of a suitable technology roadmap within the service industry is desirable. A handful of case studies have been conducted in order to fill this gap. However, these studies describe ex-post what has happened. It is not possible to follow the decision making process why certain variables are taken into account for the customization process and how the technology roadmapping process is adapted based on these variables. In addition, the conducted case studies have failed to take the complexity of services into account as the presented roadmaps are rather simplistic. This study aims at filling this gap.

Research design

At the same time a service-oriented firm had a practical problem because they had wanted to create an overview of which market trends they should follow the coming decade. In addition, they wanted to know how they should react upon these market trends with their services and technologies. In order to fulfill this practical wish and to contribute to the academic community an action research approach has been chosen. This had the aim of answering the following central research question:

- What constitutes a suitable technology roadmapping process for a service-oriented firm?

In order to answer this research question a framework was designed. Through a literature study, consulting company documents, observations and validation meetings a technology roadmapping implementation plan was designed. Subsequently, this plan had to be implemented and based on four pillars of suitability evaluated. Thereafter conclusions should be drawn and recommendations had to be given.

Methods

A variety of methods have been used to achieve the main goal of this thesis. As the study aims at obtaining an understanding of what constitutes a suitable technology roadmapping process within a service-oriented firm purposive sampling has been used to select a case. Thereby the case possesses characteristics which are relevant to the phenomenon being studied. This study has used four different data collection procedures: (1) studying existing documents, (2) focus groups, (3) interviews and (4) observations. The data has been analyzed through a within case analysis.

Theoretical framework

A literature review has been conducted to obtain an understanding of the most crucial aspects of designing and implementing a technology roadmapping process. The following definition has been used for a technology roadmap: "documents that recognize the key defining parameters of the markets, products, and technologies for one part of the business". The architecture of a technology roadmap consists out of two key dimensions: the time frame and the layers of the roadmap. The layers act as the subjects of the roadmap, while the developments of these subjects are projected on a timeline.

A technology roadmap is the outcome of a technology roadmapping process. This has been conceptualized as "a structured set of activities aimed at integrating short- and long-term knowledge from the market, products, services and technology, leading to a map of unfolding evolution of technologies and product or services that implement them to ensure that the required technologies will be available when needed". The process consists out of three main phases. First, the planning phase has the purpose of creating awareness of the value and to develop an understanding of the method. Top-management support should be obtained and an implementation plan needs to be developed. The development phase encompasses the implementation of the technology roadmapping process. In this thesis this has been done through organizing a series of workshops, whereby each layer of the roadmap acted as the subject of one workshop. Experts were invited to analyze data and to share their knowledge which resulted in the creation of a roadmap. The last phase of the process is aimed at integrating the technology roadmapping process within the existing process of the firm. Thereby it should become an ongoing process.

A key aspect of the technology roadmapping process is the customization. Scholars advocate that a roadmap should be adapted to the characteristics and context of a firm to obtain an optimal result. Customization can be applied to the architecture and the process design. Customization of the architecture means that layers of the roadmap are added or deleted and that the timeframe is adjusted. Customization of the process design refers to adapting the agendas of the workshops in such a fashion that they lead to the desired outcome.

The last section of the theoretical framework was used to obtain an idea of the current state-of-the-art of technology roadmapping within the service industry. In the service literature the importance of the synthesis stream has been acknowledged. This stream focuses on bringing manufacturing and services research together instead of studying them separately. This led to the integration of the product-service system concept within technology roadmapping. The aim of these roadmaps is to integrate related services and products into one roadmap because single products are no longer sufficient to satisfy customer needs. Previous service roadmaps simply added a service layer to the generic roadmaps or substituted the product layer for a service layer.

Conclusion

Four pillars have been used to assess the suitability of the technology roadmapping process. The first aspect encompassed finding the correct variables upon which the decision is made to customize the architecture of the roadmap. Subsequently, the second aspect relates to how the TRM architecture should be customized based on these variables. Three of the four variables have been correctly chosen and the technology roadmapping process has been customized accordingly. No other variables could be identified in retrospect. Therefore the conclusion is drawn that the key variables upon which a service-oriented firm should customize their architecture have been identified. In

addition, the architecture has been customized in such a fashion that the main goal of the process has been achieved. It is concluded that the architecture has been customized properly based on the identified variables.

The third aspect of the process involved the customization of the process design. There were no large problems with the outcomes of the market, product-service and roadmapping workshops. However, during the technology workshop a problem did rise as a limited amount of technologies had been identified. Based on the scarcity of identified technologies combined with a doubt regarding the added value of the workshop it was decided to delete the system layer from the TRM architecture. Instead a technology-push workshop was organized which was in essence a gap analysis because this was not done in the previous workshop. The activities of each single workshop have led to appropriate results. This is important to consider because the output of one workshop serves as input for the following. This shows that the process design was properly developed.

The last step for assessing the suitability of the roadmap encompassed evaluating the success of the outcome. The roadmap gives the company a good view of how they should adapt their services and technologies in order to satisfy market drivers within the coming ten years. This indicates the overall success of the roadmap has been proven. Based on the evaluation of the identified variables, the customized architecture, the customized process design and the overall outcome it can be stated that for a first test-run the process has been successful. This supports the design of a suitable TRM process for a service oriented firm.

Compared to generic TRM frameworks the findings show that the TRM process within this service firm deviates in multiple ways. First, an integrated layer of products and services fits within a service firm because of the fading boundaries between products and services. Second, participants have to be pushed to go beyond the term of a long-lasting contract. Third, making a differentiation between the user and customer helps with identifying features in the product-service workshop. Fourth, technologies were relatively difficult to identify on the roadmap mainly because of the used methodology, the organizational structures and the nature of the service.

Recommendations

The following practical recommendations are given specifically for managers who manage or want to manage a TRM process within a service-oriented firm. First, for a manager of a firm where the concepts of products and services are used interchangeably it is helpful to implement an integrated product-service layer in their TRM process. The main advantage of this is that the focus is on the core offerings of a company. Second, managers of service oriented firms where the user differs from the customer are encouraged to make to same differentiation in the product-service layer. The application of this distinction helps to identify diverse features on the roadmap. Third, a practitioner of a service oriented firm is discouraged to implement a systems layer in their TRM process. The main reason for this is that the systems and architecture of a service are dynamic. This means that these change over time and that an assessment of how a feature influences the current architecture makes little sense as the architecture might look different at the time when the feature is implemented.

Besides managerial recommendations there are several opportunities for future academic research in the field of technology roadmapping. First, a systemic customization framework has not been developed yet. A possible first step towards a proper customization process is to conduct empirical

research by looking retrospectively which variables have had a significant effect on customization. Second, additional studies that incorporate an action research approach can enhance the insights into technology roadmapping. The advantage of action research is that it does not rely on the memory of respondents. Furthermore, researchers can design and test frameworks that they have designed themselves. By obtaining an understanding of the choices that the researcher makes in the customization process would be both practically and theoretically helpful. Third, technology roadmapping within the service industry is still an underexposed research topic. The service industry is becoming increasingly relevant because of the shift towards services. Additionally, the integration of products and services raised a lot of awareness. Exploring the integration of topics such as product-service system within technology roadmapping is therefore interesting. More in-depth studies are necessary to obtain a better understanding of these phenomena.

Preface

Innovation has been the focal point of interest during my study period. At the time that my master study in Twente came to its end the opportunity to enroll in the master program innovation management and entrepreneurship of Technical University of Berlin occurred. After two semesters with interesting courses the real deal still had to be done: writing the master thesis.

With the help of Katharina Hölzle's connections I was fortunate to conduct a project at Toll Collect. The combination of theory and practice has been an ideal combination. Academic literature has been used as a solid foundation for the design of a technology roadmapping process. Subsequently, by actually implementing the process valuable information was obtained and conclusions could be drawn regarding service roadmapping. The fact that the implemented process had direct value for the company was certainly satisfying.

During the entire period of writing my master thesis I had a lot of support. As pointed out earlier, without the help of Katharina Hölzle I would probably not have got in touch with Toll Collect. In addition, her feedback and tips helped me a lot during the design of roadmapping process and writing my thesis. The feedback from Erwin Hofman, my supervisor from Twente, was also welcome. Especially his tips on the research design and structuring the thesis properly helped me a lot. My family, friends and girlfriend also deserve a note of credit here. I am sure that at some point I drove them crazy with my talk about roadmaps.

During my time at the company I have always felt welcome and the freedom of carrying out this project helped me with my professional development to a great extent. First of all, I would like to thank everyone at the PPM department. With Thies and Volker I have had great discussions and they supported me splendidly during the entire time of the process. I could always throw my ideas at Burkhard and get creative feedback. I would also like to thank Corinna for keeping an eye on the quality of the content of the roadmap and her ideas for the process. In addition, the support and input of Katharina, Klaus, Gunnar, Mark and Matthias has been great. Second of all, during my first two months I was located at the SUE department. Also there I had a lot of support from Michael, Stephan, Olaf, Gillian, Gerrit, Thomas, Jörg and Navina. Lastly, the quality of the roadmap falls or stands with experts who are present during the workshop. Therefore I would like to thank Christine, Thomas and Sandra for their technical input.

Designing and implementing a technology roadmapping process has certainly been a challenge, but along the journey the results have been interesting and I hope this is reflected in the following thesis.

Robin Barwegen
Deventer, November 27th, 2013

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List of abbreviations

CAR	Canocial action research
e.g.	Exempli gratia
EIRMA	European Idustrial Research Management Association
PSS	Product-service system
R&D	Research and development
RCA	Research-client agreement
TRM	Technology roadmapping

1 Introduction

This chapter aims at introducing the topic of this master thesis. First the practical relevance of the study is presented. Subsequently the research context, research objective, research framework, research questions and the conceptualization are given.

1.1 Practical relevance

Germany is a major transportation hub within Europe. Every day thousands of trucks from all over Europe pass through the country and use the roads. Especially heavy trucks are a burden for the quality of the roads. Therefore the German government wanted to implement a method whereby trucks, weighing more than twelve tonnes, were charged per driven kilometer within Germany. The high specialization of this task made it difficult for the government to execute it entirely by themselves. In order to obtain funds for the maintenance of the roads a contract with an external company that had the responsibility of collecting the toll was made up in 2002. This company was Toll Collect (hereafter called TC).

TC is a consortium which is made up out of three shareholders. Daimler Financial Services AG is highly specialized in financial services and has 45% of the shares. Deutsche Telekom has the same amount of shares and is known for their expertise in telecommunication services. The remaining shares are owned by the French company Cofiroute. This firm manages the roads within the Western part of France and in exchange has been enabled to charge tolls. The bundling of knowledge and expertise of these companies enabled the creation of the world's first stable and reliable satellite-based truck toll system. After a delay the system has been implemented on January 1st 2005. A more detailed overview of the activities of TC can be found in appendix A.

The service that TC delivers to the government is to transfer the toll on time. The obligations and duties that define this service have been captured in a binding contract. Thereby the activities that TC can perform are legally defined. It may do no more, no less. If the company wants to add or delete activities the contract needs to be renewed. Such contract renewals can take months or even years. An activity that the company wants to perform in two years has to be known and secured in the contract right now.

The contract is coming to its end in 2015 and the company wants to get an overview of the market trends they need to follow the coming decade. Subsequently, an overview needs to be created which displays how TC should react upon these drivers with its services and technologies. Thereby the company has the opportunity to fix certain features or activities in the contract which they want to carry out in the coming ten years. In order to achieve this goal a technology roadmapping process is going to be implemented. This method has the potential of establishing linkages among the most important market trends, the evolution of services and the development of technologies that enable these services in one overview.

1.2 Research context

The importance of services has increased rapidly over the last decades (Shugan, 1994; Fitzsimmons & Fitzsimmons, 2000; Miozzo & Soete, 2001; Menor & Roth, 2007). Currently, services dominate most developed economies given that more than half of these countries' gross domestic product is in this sector. Services are expected to dominate the projected economic and job growth during the 21st century (Pilat, 2000). The rapid technological progress combined with the globalization of services

caused an increasing pressure for service firms to compete on new offerings (Menor, 2000). Despite the increased growth and relevance of services it is one of the least studied and understood topics in the innovation management literature (Johnson et al., 2000; Menor et al., 2002; de Jong et al., 2003). Services have traditionally been described as “high-touch, low-tech”. However, the inclusion of technologies changed their nature drastically (Bitner et al., 2000). As a result the current tactics for the developments of new services are inadequate because they are typically undertaken in a non-systemic manner and our understanding of the critical resources and activities to develop new services is inadequate (Menor et al., 2002; Gustafsson & Johnson, 2003; Thomke, 2003; Berry et al., 2006).

A potential method to fill this gap is by using a technology roadmapping (TRM) process to enhance the effectiveness of technology management. Its popularity is explained by the fact that this method supports innovation and strategic decision making at the same time (Galvin, 1998; Vatananan & Gerdsri, 2004; Phaal & Muller, 2009). Previous used methods were short-term oriented and poor in identifying technologies needed to address market demands (Kostoff et al., 2004). Over time, technology roadmapping has proven to be effective for its long-term focus (Kappel, 2001), the identification of disruptive innovations (Kostoff et al., 2004), to perceive threats in the external environment (Phaal & Muller, 2009), to enhance communication within an organization (Kostoff & Schaller, 2001) and to include the strategic dimension (Albright & Kappel, 2003).

Despite the potential of the technology roadmapping method it has mainly been applied within the manufacturing industry (Wells et al., 2004; Fouskas et al., 2005). Several scholars (Groenveld, 1997; Phaal et al., 2004b; Lee & Park, 2005) advocate that technology roadmaps need to be customized to fit with the context and characteristics of a firm. This means that technology roadmaps are highly context dependent and therefore its transferability to other contexts, in this case to service oriented firms, is questioned (Phaal et al., 2004b). Therefore research that tests the applicability of a suitable technology roadmapping process within the service industries is highly desirable (Kim et al., 2008; Geum et al., 2011a). In this light, a handful of case studies have been performed in order to understand the phenomena of service roadmapping (Wells et al., 2004; Daim & Oliver, 2008; Tuominen & Ahlqvist, 2010). However, these studies describe ex-post what has happened and what have been the focal points in these cases. It is not possible to follow the researchers’ thoughts during the design or customization process. Studies that describe which characteristics of a service oriented firm demand attention and how the roadmap should be customized accordingly are missing. In addition, the conducted case studies have failed to take the complexity of services into account as the presented roadmaps are rather simplistic.

The major theoretical gap that this research addresses is an exploration of the characteristics of a service oriented firm that demand a customization of the TRM process. In addition, current scholars have missed to explain how a TRM process should be adapted accordingly. Therefore the theoretical contribution of this research is to discuss these characteristic and subsequently explain how the TRM process is customized to suit a service oriented firm. This should lead to suitable technology roadmapping process for a service oriented firm. The practical gap that this research addresses refers to the fact that TC wants to implement a technology roadmapping process to improve the service level towards the government. A formal roadmapping process was not present and therefore the process should result into the development of a technology roadmapping process within TC.

1.3 Research objective

The research objective of this thesis and the objective in this thesis are based on the presented research context in the previous paragraph.

The objective of the research is formulated in the following way:

> *"To obtain insight in what encompasses a suitable service-oriented technology roadmapping process by assessing the suitability of a customized technology roadmapping process which is customized for and implemented within a service-oriented firm."*

1.4 Research framework

According to Verschuren & Doorewaard (2007) a research framework is an illustration of the research objective and includes the necessary steps in order to achieve it. The research framework of this thesis is formulated as follows:

(a) A study of the theories of technology roadmaps, technology roadmapping processes and technology roadmapping within a service environment results in a conceptual model (b), to be used for the implementation of a technology roadmapping process within a service-oriented firm. (c) Four criteria of suitability are used for the evaluation of the implementation that subsequently results in (d) recommendations for designing and implementing a technology roadmapping process within a service-oriented firm. Figure 1 illustrates this research framework.

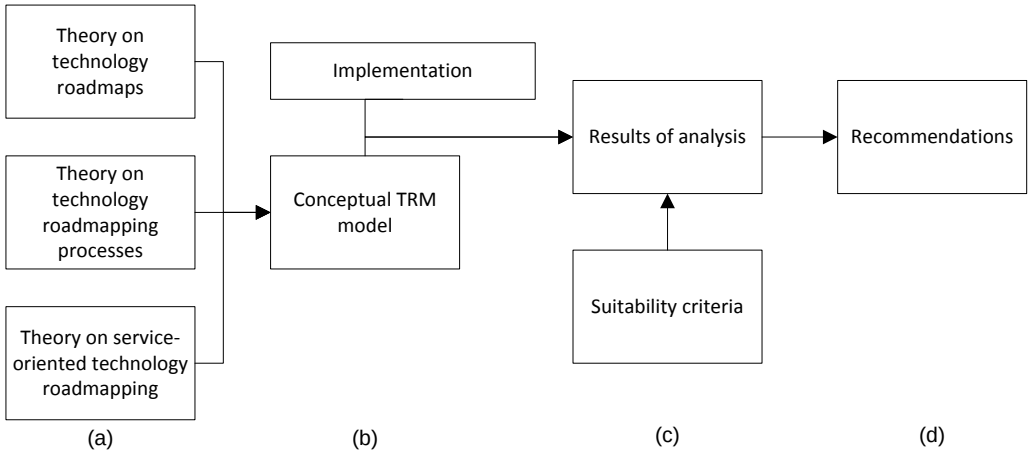

Figure 1: Research framework

1.5 Research questions

The research objective has lead to the central research question which is captured in the following way:

Central research question

- What constitutes a suitable technology roadmapping process for a service-oriented firm?

In the central research question the term suitable refers to the fact whether the technology roadmapping process fits with the firm for which it is designed. In order to assess the suitability of the TRM process for a service oriented firm four aspects are taken into account, namely the variables upon which the decision is made to customize the architecture, the success of customizing the

architecture, the success of customizing the process design and the success of the outcome. It is articulated within the scientific literature that a technology roadmapping process should be customized in order to fit with the characteristics and context of the firm (Groenveld, 1997; Phaal et al., 2004b; Lee & Park, 2005). Therefore the first aspect relates to whether the correct characteristics have been chosen in order to adapt the architecture of the TRM process. Phaal et al. (2004b) state that the actual customization process consists of both adapting the architecture, which refers to choosing the layers or subjects of the roadmap, and customizing the process design. This encompasses the adaption of agendas of the workshops. Last, Gerdrsri et al. (2010) argue that the success of a TRM process should be judged on to what extent the goal of initiating a TRM process has been achieved. Therefore these four criteria have been used to assess the suitability of the TRM process.

Sub questions

Seven sub-questions have been created which help with answering the central research question. These sub-questions have been designed in such a way that they are steering and efficient as Verschuren & Doorewaard (2007) explain. The first set of sub-questions concern the customization process of both the architecture and process design. The second set of sub-questions relate to evaluating the suitability of the implemented TRM process. Here the four pillars are taken into account. Both sets questions are helpful because they guide the research project towards developing a conceptual TRM model for TC and subsequently by evaluating this conceptual model.

For developing a suitable conceptual TRM process for TC the following sub-questions have been created:

1. Which characteristics of TC affect the customization of the architecture of a technology roadmapping process?
2. How do the identified characteristics of TC affect the customization of the architecture of a service-oriented technology roadmapping process?
3. How does the customized architecture subsequently affect the customization of the process design of a service-oriented technology roadmapping process?

In order to assess the extent to which the implemented TRM process was suitable for TC the following sub-questions have been developed:

4. To what extent has the architecture been customized based on the correct characteristics of TC?
5. To what extent has the architecture of the TRM process been customized properly?
6. To what extent has the process design of the TRM process been customized properly?
7. To what extent has the TRM process been a success?

1.6 Conceptualization

Having elaborated on the research questions of the thesis it becomes evident to conceptualize the terms that have been used. In order to create a clear understanding the main terms are explained.

1.6.1 General concepts

Important definitions of concepts that have been used in this thesis are presented in table 1.

Concept	Definition	Source
Technology	"The practical application of scientific or technical knowledge."	Dorfman (1983, p. 300)
Feature	"An end user visible characteristic of a system."	Kang et al. (1990, p. 28)
Product-service system	"A marketable set of products and services capable of jointly fulfilling a user's needs, provided by either a single company or a strategic alliance of companies."	Goedkoop et al. (1999, p. 111)
Product	"A tangible commodity, manufactured to be sold in large quantities. It is capable of falling onto your toes and of fulfilling a user's need."	Goedkoop et al. (1999, p. 111)
Service	"An activity (work) done for others with an economic value and often done on a commercial basis."	Goedkoop et al. (1999, p. 111)
System	"A collection of elements including their relations. Elements can be material or immaterial. The hierarchic level, system boundaries and relations are defined mainly as a result of the researcher's aim."	Goedkoop et al. (1999, p. 112)

Table 1: Definitions of most important used concepts

1.6.2 Technology roadmapping process

In order to clarify the concept of a *technology roadmapping process* the term *technology roadmapping* is explored first. Phaal et al. (2004b, p. 31) explicitly mention knowledge management in their definition: "Technology roadmapping is a practical action-oriented tool for supporting knowledge management in an organization". Garcia & Bray (1997, p. 9) clearly focus on the development of a map with technologies: "Technology roadmapping […] is an effective technology planning tool to help identify product needs, map them into technology alternatives, and develop project plans to ensure that the required technologies will be available when needed. Groenveld (2007, p. 50) emphasizes the integration of the strategic dimension in his definition: "Roadmapping is a process that contributes to the integration of business and technology and to the definition of technology strategy by displaying the interaction between products and technologies over time, taking into account both short- and long-term product and technology aspects".

Subsequently, a *process* within a business context is "a structured, measured set of activities designed to produce a specific output for a particular customer or market. […] It has a specific ordering of work activities across time and space, with a beginning and an end, and clearly defined inputs and outputs" (Davenport, 1993, p. 5).

A combination of the above presented definitions complemented with the concept of services has led to the following conceptualization of a technology roadmapping process in this thesis: "A technology roadmapping process is a structured set of activities aimed at integrating short- and long-term knowledge from the market, products, services and technology, leading to a map of unfolding

evolution of technologies, product and services that implement them to ensure that the required technologies will be available when needed".

1.6.3 Technology roadmap

As the outcome of a technology roadmapping process is a technology roadmap it is subsequently necessary to conceptualize a *technology roadmap*. Although several different definitions exist (see appendix B), the definition of Kappel (2001, p. 41) will be used as this definition fits the best with the overall aim of the thesis. The inclusion of the service concept was lacking in all identified definitions. Therefore this was added to Kappel's (2001) conceptualization: "A document that helps the viewer recognize the critical definitive factors in the market, product, service, and technology, which form a part of the business".

1.6.4 TRM implementation

The dictionary indicates that implementation means: "To put into effect according to some definite plan or procedure". Therefore in the context of this thesis it means to "put the technology roadmapping process into effect".

2 Methodology

This chapter contains the methodology that has been applied within this thesis. The research strategy is elaborated on first. The methods and data analysis are subsequently presented.

2.1 Research strategy

This section first described the selection of the research strategy and subsequently presents the general implementation strategy of this research strategy.

2.1.1 Selection of the research strategy

The type of research strategy should fit with the objective of the study. The objective of this study is twofold: doing research in order to answer the research question and to fulfill a practical need. The researcher is therefore actively engaged in designing and carrying out the TRM process. This is a typical objective of action research which is defined as "the active and deliberate self-involvement of the researcher in the context of his or her investigation" (McKay & Marshall, 2001, p. 49). Case studies and action research are related in the sense that the researcher is concerned with gaining an in-depth understanding of a particular phenomenon in real-world settings (Blichfeldt & Andersen, 2006). However, it should be taken into account that there are clear differences between the two approaches. Case researchers mostly use information from participants in to order to do research about phenomena prior to doing the study. Action researchers need to collaborate with participants during the study to successfully solve a practical problem. Additionally, case researchers are mostly targeting the academic community, while action researchers at the same time have an obligation to inform the people for whom they solved the practical problem. Grønhaug & Olsson (1999) explain that action researchers therefore tend to forget to report how they conducted their research in detail which diminishes their academic contributions. In order to increase the academic acceptance of their work action researchers should replace hypotheses with themes by presenting an intellectual framework of ideas in advance (Yin, 2003; Checkland & Holwell, 1998; Blichfeldt & Andersen, 2006). Generally, action researchers leave it up to the reader how to interpret their outcomes (Coghlan, 2003), while case researchers apply analytical generalizations of their results. In order to increase the value of their research it is therefore recommended that the action researcher explains the reason why his or her outcomes interest others (Coghlan, 200; Blichfeldt & Andersen, 2006).

2.1.2 Implementing action research

Multiple frameworks exist to guide the process of action research (Lewin, 1951; Susman & Evered, 1978; McFeeley, 1996). As the process of TRM fits perfectly with the framework of Susman & Evered (1978) this will be used as the base of carrying out the research. The framework consists out of five major steps. Figure 2 illustrates the framework.

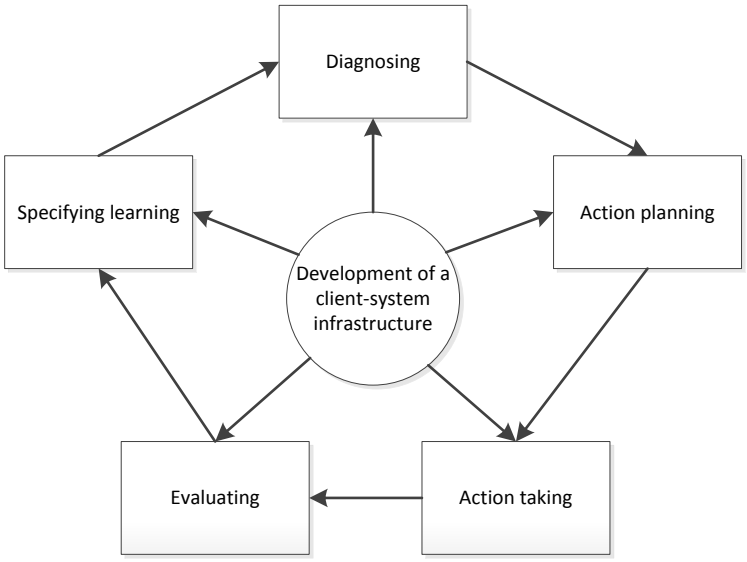

Figure 2: Action research model adapted from Susman & Evered (1978)

All five phases of the framework are necessary to carry out a comprehensive action research. The researcher starts with diagnosing the situation. A concrete problem statement is identified that subsequently leads to the research objective and question. A plan is developed and implemented to reach the objectives of the study and to answer the research question. Finally, the actions should be thoroughly evaluated and the lessons that were learned need to be specified. Figure 3 illustrates how the model of Susman & Evered (1978) has been applied. The following sections of this chapter explain these steps in-depth.

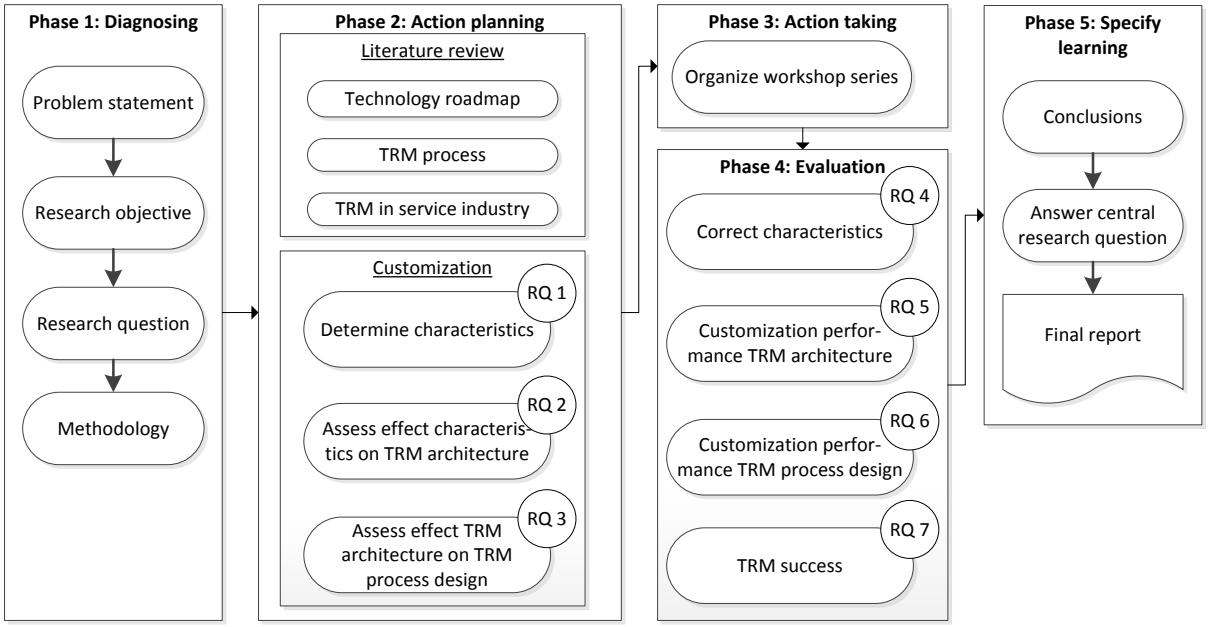

Figure 3: The applied research model

2.2 Methods

This section aims at describing the methods that have been used in this thesis. The case selection is dealt with first. Second, the unit and level of analysis are described. Within the last section the data collection methods of this research are presented.

2.2.1 Case selection

The selection of cases is important when conducting an in-depth study as the generated theory is build on information derived from the cases. The selected case should address the purpose of the study, which is also known as purposive or judgmental sampling. This form of sampling is a form of non-probability based selection where the researcher judges the usefulness of the case in order to understand the studied issue and to answer the research questions (Babbie, 2007). The purpose of this type of sampling is to identify cases which possess characteristics which are relevant to the phenomenon being studied. Thereby the exploration of a particular phenomenon is enabled (Mays & Pope, 1995). In this case, the researcher wants to do research about the suitability of a TRM process within a service-oriented firm. Therefore a service-oriented firm has been chosen as the case.

2.2.2 Unit and level of analysis

In order to establish the scope of the research, the unit and level of analysis have to be considered (Yin, 2003). Units can be people, time periods, institutions, or almost anything else that is studied (Shadish et al., 2002). In this study the unit of analysis is the technology roadmapping process within a service oriented firm.

A distinction into different phase of the research led to differentiated levels of analysis. During the customization process the level of analysis will be TRM team while an expert panel is the level of analysis during the development phase. This expert panel will consist out of experts from different departments and therefore are an ideal level of analysis. During the evaluation process of the entire project the level of analysis will be the interviewees.

2.2.3 Data collection

To obtain sufficient data for drawing conclusions multiple data collection procedures are used. Multiple scholars have supplemented an action research strategy with case research methods (Iversen et al., 2004; Ray & Ray, 2006). Within action research the researcher and participants of the organization work closely together. By adopting case research methods the risk of uncontrollability and too much subjectiveness is reduced (Kock, 2004). This study has used four different data collection procedures: (1) interviews, (2) studying existing company documents, (3) observations and (4) focus groups. The use of multiple methods enhances data credibility and enables triangulation (Eisenhardt, 1989; Yin, 2003). The different data sources are one piece of the “puzzle”, whereby each piece contributes to the understanding of the complete phenomenon (Baxter & Jack, 2008).

2.2.3.1 Interviews

During the evaluation phase multiple interviews with participants have been held in order to validate the outcome the workshops. Qualitative interviews are an interaction between the researcher and the respondent in which the researcher has a general plan, in this case to validate the outcome, but not a specific set of questions that must be asked (Babbie, 2007). However, for every interview a guideline was developed to make sure that essential questions were asked. Interviews are a great way to obtain in-depth and rich information, especially to gather information about ideas and perceptions of individuals (Baarda et al., 2005). Therefore this method serves the purpose of validating the previously established content perfectly. The interview protocol can be found in appendix C.

2.2.3.2 Studying existing company documents

The outcome of the action planning phase resulted into a customized TRM framework. The characteristics of the firm and the purpose of the roadmap affect this process. Therefore academic literature was consulted to check what type of generic framework is suitable for the specific purpose of the firm. Internal documents have been studied to find out the characteristics of the case that deviate and need customization. Additionally, once these characteristics had been found an additional literature study was conducted to explore the effect on service innovation and new service development. As Babbie (2007) explained internal documents are a valuable unobtrusive source of information because these sources are most likely of high quality.

2.2.3.3 Observations

The researcher was located within the organization for five months. During this period several meetings have been attended and five workshops have been organized. Babbie (2007) explains that it is vital to make full and accurate notes of what goes on. Therefore a log of all meetings has been kept (see appendix D). This log contains the dates, duration, names, positions of the participants and what was learned from these meetings. This log served to keep an overview of all the conclusions that were drawn during the meetings. Within this log references are made to documents with a more extensive elaboration of what happened during a meeting or workshop. These documents were written as soon as the meeting was over as Babbie (2007) recommended.

2.2.3.4 Focus groups

The focus group method is essentially a qualitative method which allows the researcher to question multiple individuals systematically and simultaneously. The participants are chosen on the basis of the relevance to the topic (Babbie, 2007). This method is used in the development phase as it is essential for the creation for introducing an appropriate technology roadmapping process at a service oriented firm. In order to obtain data from relevant different points of view, the participants of the focus group are chosen based on their expertise and is therefore a type of purposive sampling. Their expertise is linked to one of the different subjects of the roadmap. Thereby every subject has an expert within the focus group. Advantages of the approach are the flexibility, high face validity, speedy results and capturing real-life data in a social environment (Krueger, 1988). Every method has its disadvantages and this case the challenge lies in the moderating skills of the researcher (Babbie, 2007). Within a group of people the researcher will probably have less control than with the use of individual interviews and therefore they need special skills (Krueger, 1988). Other challenges are the fact that data is difficult to analyze and groups are difficult to assemble (Krueger, 1988). These challenges has been tried to overcome through the fact that the researcher was not the mediator during the workshops, therefore he was able to observe and document what happened. Although the mediator did not have experience with this particular method, he did have experience in mediating workshops. The assembly of the groups caused not that much trouble because attendance had been made obligatory for product managers that worked with the special product family. In addition, several employees of other departments were eager to join the workshops because they showed interest in the method and the research project.

2.3 Data analysis

The data of this study is gathered from one case, therefore it is considered as a within case analysis. The idea of a within case analysis is to become familiar with the case as a stand-alone entity (Eisenhardt, 1989). The collection of data led to a large amount of information which needs to be

processed, analyzed and interpreted in order to draw conclusions. Two analyses have been made, one for the development of the customized TRM framework and one to evaluate the actions that have been made.

2.3.1 Customization

A customization framework was developed to create a conceptual TRM process for TC. Several methods were used to look for indicators that could demand a customization of the generic TRM process. These were sought for through observations, reviewing academic literature and using secondary sources which were present within the organization. These were discussed within meetings to obtain the opinion of the TRM team who have a great understanding of the organization. Additionally, a feedback loop was included. This had the purpose of reviewing potential relevant variables that the experts had indicated within the validation meetings. This two-stage model enables triangulation of data. A total of seventeen meetings have been held to fit the TRM framework to the needs and characteristics of the organization.

2.3.2 Evaluation

The framework of Creswell (2009) was used for the evaluation process. This framework encompasses five steps that need to be taken.

1. Organizing and preparing the data for analysis. Summaries of all meetings have been documented in separate files. One central log was kept where all key points are displayed with a further reference to a detailed file of the meeting. Thereby the central log functions to keep the overall overview and if needed further details can be checked in the individual files. An overview of the central log can be found in appendix D.
2. Read through all the data. The development of the log enables to go through all the data in a convenient manner.
3. Coding. Transcripts of all evaluations have been developed and these have been open coded. This enables the researcher to check relevant codes during the analysis. As the evaluation interviews had been structured in the same way as the findings section in a thematic sense the data could be consulted in an efficient way.
4. Generate descriptions and themes and interrelate them. This step is very closely connected to the coding because the interviews had been structured into themes already. This resulted into the findings section.
5. Interpretation of the data. This step resulted into the discussion, conclusion and recommendation sections. In the discussion the data was interpreted compared to existing literature while the conclusion section displays the key findings. Additionally, managerial and theoretical recommendations were made based on the interpreted data.

2.4 Quality of analysis

The analysis of the quality of the research has been separated into two parts. Although some action researchers articulate that action research should be judged within its own terms, case study methods have been used for the collection of data. For the completeness of this analysis the validity and reliability are therefore discussed.

2.4.1 Action research quality criteria

Action research should be justified within its own terms, it does not have to be judged in relation to other paradigms and research approaches (Susman & Evered, 1978; Aguinis, 1993; Cunningham,

1993). Coughlan & Coghlan (2002) state that other types of research do not have fewer threats to validity than action research. However, the threats should be identified and assessed. The criteria developed by Davison et al. (2004) have been used to determine the quality of the action research. These criteria are based on the action research framework of Susman & Evered (1978) that was presented earlier. Davison et al. (2004) refer to canocial action research (CAR) which is the type of action research Susman & Evered (1978) have adopted. A table of the criteria is given first. Thereafter these criteria are discussed.

2.4.1.1 Principle of the Research-Client Agreement (RCA)

1a	Did both the researcher and the client agree that CAR was the appropriate approach for the organizational situation?
1b	Was the focus of the research project specified clearly and explicitly?
1c	Did the client make an explicit commitment to the project?
1d	Were the roles and responsibilities of the researcher and client organization members specified explicitly?
1e	Were project objectives and evaluation measures specified explicitly?
1f	Were the data collection and analysis methods specified explicitly?

Table 2: Criteria of the principle of RCA

Both the researcher and the client agreed that CAR was the appropriate approach the organizational situation. The organization had a practical challenge that demanded the introduction of TRM process while the researcher was interested in what constitutes an appropriate TRM process for a service oriented firm (1a). The focus of the research was specified clearly and explicitly. An initial meeting was devoted to determining the scope of the research. Subsequently, the researcher explicitly mentioned the research questions (1b). Commitment to the project was made through several means. First, the researcher was employed for five months for this specific task. Second, a TRM team consisting of three members was assembled. Third, resources were devoted to the facilitation of several workshops (1c). The roles and responsibilities of the researcher and client organization were specified. The two internal employees which made up the TRM team had the task of supporting the implementation of TRM process within the organization. They had the knowledge of the organization and services, while the researcher had the methodological knowledge (1d). The objectives and evaluation measures were explicitly specified. Two meetings during the start of the project had the aim to determine the exact objectives of the process. Subsequently, these objectives served as evaluation measures (1e). The data collection and analysis methods were explicitly mentioned. Chapter 2 is devoted to the research design and methodology (1f). From the given evidence can be derived that the principle of the research-client agreement was met to a high degree.

2.4.1.2 Principle of the Cyclical Process Model

2a	Did the project follow the CPM or justify any deviations from it?
2b	Did the researcher conduct an independent diagnosis of the organizational situation?
2c	Were the planned actions based explicitly on the results of the diagnosis?
2d	Were the planned actions implemented and evaluated?
2e	Did the researcher reflect on the outcomes of the intervention?
2f	Was this reflection followed by an explicit decision on whether or not to proceed through an additional process cycle?
2g	Were both the exit of the researcher and the conclusion of the project due to either the project objectives being met or some other clearly articulated justification?

Table 3: Criteria of the cyclical process model

The project followed the original research model which was a CAR process model. No deviations were made (2a). The researcher conducted a literature review first; hereafter a diagnosis was made of the organizational situation based on the literature review (2b). The diagnosis resulted in a customization framework which subsequently served as the action plan (2c). The action plan was implemented only to certain degree. During multiple workshop iterations were needed because there was not enough time left to complete all the activities. One workshop has been changed entirely. The actions were evaluated afterwards (2d). The researcher has reflected on the outcomes of the intervention extensively in chapters 5 and 6 (2e). An explicit decision whether an additional process cycle will follow has not been made yet. However, unofficial plans are currently developed to implement another process cycle for other product-families (2f). The contract of the researcher ran for the time of the process and the objectives had been reached by the time that the researcher left (2g). The principle of cyclical process can be judged as sufficient. Because of the deviation of the original plan the fourth workshop was not carried out. After the third workshop a decision was made to change the goal of the fourth workshop due to an insufficient outcome of the third workshop.

2.4.1.3 Principle of Theory

3a	Were the project activities guided by a theory or set of theories?
3b	Was the domain of investigation, and the specific problem setting, relevant and significant to the interests of the researcher's community of peers as well as the client?
3c	Was a theoretically based model used to derive the causes of the observed problem?
3d	Did the planned intervention follow from this theoretically based model?
3e	Was the guiding theory, or any other theory, used to evaluate the outcomes of the intervention?

Table 4: Criteria of the principle of theory

The project activities were guided through multiple guidelines published in academic journals. Additionally, methods for the workshop were also chosen based on academic conclusions of scientific papers (3a). The domain and specific setting of the organization were relevant for the interest of the research's community. Purposive sampling was used to study a service oriented firm (3b). A model based on existing principles has been developed to identify and assess variables that demand customization of the generic product-technology framework (3c). The workshops were planned based on the customization framework (3d). The guiding theory proposed to conduct a review and to establish revision methods (3e). The above elaboration indicates that the principle of theory has been met.

2.4.1.4 Principle of Change through Action

4a	Were both the researcher and client motivated to improve the situation?
4b	Were the problem and its hypothesized cause(s) specified as a result of the diagnosis?
4c	Were the planned actions designed to address the hypothesized cause(s)?
4d	Did the client approve the planned actions before they were implemented?
4e	Was the organization situation assessed comprehensively both before and after the intervention?
4f	Were the timing and nature of the actions taken clearly and completely documented?

Table 5: Criteria of change through action

Both the researcher and the client were motivated to improve the situation. The researcher wanted to test whether the customized TRM framework was applicable within a service oriented firm, while the client wanted to implement the TRM process to establish linkages between the market,

products/services and technologies (4a). The diagnosis of the organizational situation led to a customized TRM framework which was subsequently implemented. Therefore the problem was specified according to the diagnosis (4b). The TRM process was designed in such a fashion that it, at least theoretically, fitted with the research question (4c). A series of seventeen meetings have been conducted to design the customized framework. This was done in collaboration with TRM team (4d). The implementation of TRM process was not done previously, so both the before and after situation have been assessed properly (4e). The researcher kept a log of all attended meetings and workshop. Time, date and content are specified in these documents (4f). The principle of change through action was met based on the given explanations.

2.4.1.5 Principle of Learning through Reflection

5a	Did the researcher provide progress reports to the client and organizational members?
5b	Did both the researcher and the client reflect upon the outcomes of the project?
5c	Were the research activities and outcomes reported clearly and completely?
5d	Were the results considered in terms of implications for further action in this situation?
5e	Were the results considered in terms of implications for action to be taken in related research domains?
5f	Were the results considered in terms of implications for the research community (general knowledge, informing/re-informing theory)?
5g	Were the results considered in terms of the general applicability of CAR?

Table 6: Criteria of learning through reflection

Several meetings with the head of the product management department have been held, together with seventeen meetings with TRM team. The organization was aware of the progress (5a). Several evaluation meetings have been held with employees of the organization. Additionally, a reflection of the researcher is presented in paragraph 7.4 (5b). Within the findings quotes of the evaluation interviews have been given that gives the reader the opportunity to make its own assessments and interpretations. However, due to a confidentiality agreement not all information could be specified. The assessment whether the results have been reported clearly is difficult to make by the researcher himself, however an extensive documentation of process has been made (5c). Practical and academic recommendations have been presented in chapter 7 (5d, 5e & 5f). An evaluation of the generalizibility of the findings has been provided in the conclusions section (5g). The outcomes of the criteria indicate that the principle of learning through reflection has been reached.

2.4.2 Validity and reliability

Validity refers to the extent to which an inference is supported by relevant evidence and reflects the real meaning of it (Babbie, 2007; Shadish et al., 2002). In qualitative research it is seen as the extent of how accurately the participants' representations of a social phenomenon have been captured (Creswell & Miller, 2000). In order to judge the credibility of the study three types of validity are discussed.

The term internal validity is used to describe to what extent conclusions can be drawn from observations reflecting a causal relationship (Shadish et al., 2002). Drawing causal conclusions is generally not the aim of qualitative studies. However, in qualitative studies internal validity refers to the fact whether there are alternative explanations for the phenomena being studied (Yin, 2003). Several methods have been suggested to ensure internal validity such as low inference descriptors, several forms of triangulation, using participant feedback, peer reviews, negative case sampling,

reflexivity and pattern matching (Johnson, 1997). This study adopted several of these measures to ensure internal validity such as the use of multiple sources of data for triangulation. In addition, several feedback loops in form of validation meetings and interviews have been implemented in the research design.

Construct validity is used to assess to what extent was measured what was intended to measure (Babbie, 2007). This is important because constructs are the primary means to connect operational measures to theory in a study. Wrongly measured constructs can lead to misleading conclusions (Shadish et al., 2002). Therefore constructs should be created in such a way that it covers a concept completely and should not contain aspects that not fit with the concept (van Aken et al., 2007). In case based research construct validity can be enhanced by the use of multiple sources of evidence, establishing a chain of evidence and to have key informants review the draft case study report (Yin, 2003). In this case several measures have been used to ensure construct validity. A chain of evidence is established and multiple sources of evidence have been presented in the form of several reflections. Additionally, multiple key informants have reviewed drafts of the report.

External validity means the extent to which findings can be generalized to other persons, settings and times (Shadish et al., 2002). Generally, case studies are very weak in its generalization for two reasons. First, samples are rarely randomly selected in case studies and therefore are very limited in their reflection of a larger population. Second, generalizability is not the major purpose of qualitative research. The purpose is not to obtain general findings which are applicable to a larger population, but to gain understanding of a phenomenon in a unique setting (Johnson, 1997). The last certainly holds for this study, but through the transparency of the used methods other scholars can attempt to replicate the study. However, it should be taken into account that this study only encompasses one case which limits the external validity to a large extent.

Reliability means whether another researcher would reach the same results when conducting the exact same study (Yin, 2003). This is one of the main instances why scholars say that action research should be judged based on its own methods as the presented study simply cannot be exactly replicated because the context evolves over time. Therefore, reliability within qualitative research refers to the transparency and verifiability of research procedures, results and conclusions (Creswell, 2009). Specifying details of the used methods and tools enhances the reliability of this study. Interviews have been recorded and subsequently coded. In addition, all transcripts and summaries of interviews and meetings have been sent to the participants afterwards for feedback. The reliability is furthermore increased by using multiple interviewees and multiple participants in the focus groups.

3 Theoretical framework

The theoretical framework consists out of three separate parts. First, the essence of a technology roadmap is explained. Subsequently, an elaboration is given on what constitutes a TRM process. Lastly, the current state-of-the-art of TRM within the service industry is given.

3.1 Technology roadmap

This section aims at explaining the most essential aspects of a technology roadmap. This is necessary because the outcome of this thesis leads to a technology roadmap.

3.1.1 Definition

The academic and practical interest in technology roadmapping has increased rapidly over the last decades (Vojak & Chambers, 2004). The concept has been interpreted in multiple manners. Taking a strict approach the definition only includes roadmapping activities that focus on product- or process-related technologies. The multi-level perspective on roadmapping which was developed by the European Industrial Research Management Association (EIRMA, 1997) is interpreted in a broader sense. This means that all roadmapping activities concerned with technologies, products, processes, functions, market agents, competencies, projects and further aspects are included under the umbrella of technology roadmapping (Moehrle et al., 2013). The technology roadmap that has been developed for this thesis has been build upon frameworks which adopted the latter concept. Therefore the broader concept of technology roadmapping is referred to here. The following definition of a technology roadmap is followed: “Documents that recognize the key defining parameters of the markets, products, services and technologies for one part of the business” (Kappel, 2001, p 41). In essence it is agreed upon that technology roadmaps are living and versatile documents that can be used to support strategic planning and technology foresight (Kostoff & Schaller, 2001; Phaal et al., 2004a; Cosner et al., 2007).

3.1.2 Related concepts

The flexible nature of roadmapping causes confusion and overlap with many other techniques and approaches (Phaal et al., 2005). Other approaches that are often related to technology roadmapping are methods such as foresight, futures, Delphi, scenario planning and other general approaches to technology strategy development (Phaal et al., 2004a). These techniques can be related to two different views for roadmapping, namely forecasting and planning.

- Technology forecasting helps an organization by identifying reasonable goals for new development processes and includes industry specific information regarding competitive technologies. The aim of this tool is to increase the quality of technological decision making rather than making accurate forecasts. An accurate forecast for a technology with low strategic alignment has very limited value. Therefore technology forecasting should incorporate a strategic point of view (Kappel, 2001).
- Planning methods address how products and services develop over time. Where a technology forecast creates a view of how the future might look like, planning addresses how companies use this knowledge for future products or services. It is used as a tool to extend their perspectives over a longer period of time (Kappel, 2001).

3.1.3 Use of technology roadmaps

The major purpose of a technology roadmap is to portray relationships between evolving and developing markets, products and technologies over time and to align them with organizational objectives (Kappel, 2001; Kostoff & Schaller, 2001; Phaal et al., 2004a; Rinne, 2004; Gerdsri et al., 2010). By forecasting future trends and identifying gaps in the firm's current technology levels and the aspired levels, the roadmap enables a firm to carry out specific research and development (R&D) projects with an appropriate timing plan to close these gaps (Geum et al., 2011a). It is especially useful in turbulent environments to scan the environment and track the performance of individual technologies (Phaal et al., 2004a). Additionally, roadmaps are used to help identify areas which have high potential, and to accelerate the transfer towards actual products (Kostoff & Schaller, 2001).

3.1.4 Application of technology roadmaps in practice

Roadmaps are applied on various levels (Petrick & Echols, 2004). To create structure out of all these different roadmaps Kappel (2001) created a taxonomy which includes different types of roadmaps with different targets and emphasis. Figure 4 shows an overview of the different types. The left part of the figure relates to the industry level, while the right part illustrates a firm level perspective.

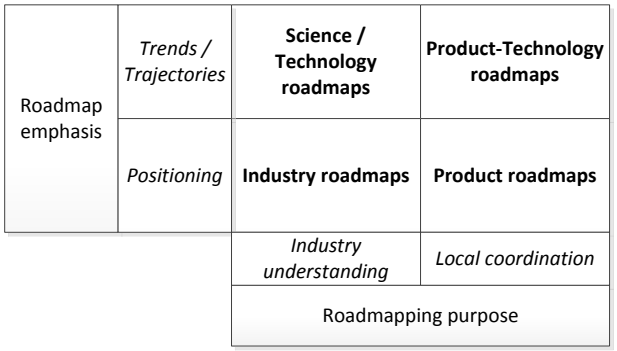

Figure 4: Taxonomy of roadmaps created by Kappel (2001)

- *Science / Technology roadmaps* are used in order to get a better understanding of the future by identifying specific trends and forecast (Kappel, 2001).
- *Industry* roadmaps are the result of forecasts combined with an industrial context. These roadmaps focus on technical trust between different actors and on the shape of the competitive landscape. These roadmaps are driven by the need for an intercompany agenda, an inter-organizational supply chain, and large capital investment (Kappel, 2001).
- *Product-Technology roadmaps* combine the marketplace, technological trends and specific product plans. This type of roadmap highlights the link between product generations and successive technology generations (Kappel, 2001).
- *Product roadmaps* are used to apply focus for the specific direction and schedule of the evolution of products. The main aim of such a roadmap is to communicate with customers and employees (Kappel, 2001).

3.1.5 Dimensions of a technology roadmap

The structure of a technology roadmap is referred to as the roadmap architecture which consists out of two key dimensions: the *time frame* and *layers* of the roadmap (Phaal et al., 2001; Phaal & Muller, 2009). Figure 5 shows the generic architecture of a technology roadmap.

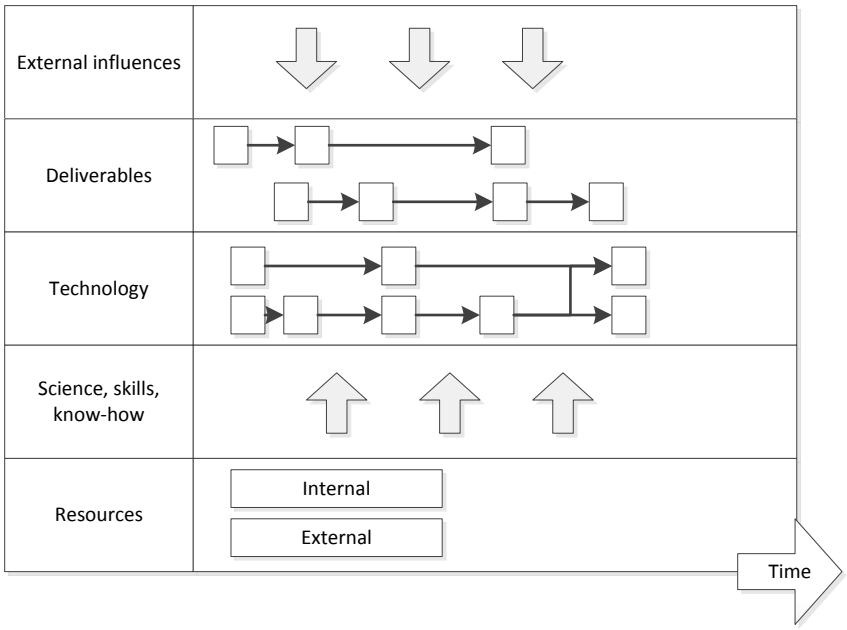

Figure 5: Generic TRM framework (Phaal & Muller, 2009)

Phaal and Muller (2009) propose that the timeframe consists of five different periods of time namely *past*, *short-*, *medium-*, *long-term* perspectives and the *vision*. The absolute timeframe depends upon the business or system of the roadmap. For many firms the appropriate time horizon is ten years, although fast-moving sectors need a shorter time frame as their product cycles are relatively shorter (Cosner et al., 2007).

The second dimension is the layers of the technology roadmap. These layers represent a systematic hierarchical taxonomy. Thereby different levels of detail can be addressed (Phaal & Muller, 2009). Roadmaps consist of three broad layers, namely the top, middle and bottom layer. The top layer displays trends and drivers that relate to the overall goals or purposes which are associated with the roadmapping activity. This layer includes the external market, industry trends and drivers. Furthermore, internal business trends, drivers, milestones, objectives and constraints are incorporated. Collectively, the type of information contained at the top layer can be thought of as representing the 'know-why' dimension (Phaal et al., 2004b). The middle layers generally relates to tangible systems that have to be created in order to respond to trends and drivers which are visualized in the top layer. This often relates directly to the evolution of products, services, infrastructure or other mechanism for integrating technology, capabilities, knowledge and resources in such a way that delivers benefit to customers and other stakeholders. The type of information contained in the middle layer can be thought of as representing the 'know-what' dimension of knowledge (Phaal et al., 2004b). The bottom layer relates to resources that are needed to develop the required products, services and systems. This includes knowledge-based resources, such as technology, skills, competences and other resources such as finance, partnerships and facilities. The type of information contained in the bottom layer can be thought of as representing the 'know-how' dimension of knowledge (Phaal et al., 2004b). Thus, the top layers is used to establish a relative priority, the middle layer extends the top layer by using forecasts to set targets, while the bottom layer links the other layers and therefore justifies R&D investments and coordinates the efforts of responsible groups.

3.1.6 Conclusion

A technology roadmap is a "document that recognizes the key defining parameters of the markets, products, services and technologies for one part of the business." (Kappel, 2001, p 41). This definition has been adopted within this thesis because it relates to the broader term of technology roadmapping. Many scholars have based their frameworks on the broader term and because these frameworks are used as the basis for this thesis the TRM in its broader sense is also adapted here. From the elaborated paragraphs it becomes clear that several aspects are important to consider regarding the development of a TRM process.

- The emphasis and purpose of a TRM process need to be identified to choose a generic framework of Kappel (2001).
- A TRM architecture consists out of layers and a timeframe (Phaal et al., 2004b). When designing a TRM process these dimensions should be taken into account.

3.2 Technology roadmapping process

An in-depth elaboration of how the technology roadmapping process should be handled is described in the next parts. The total roadmapping process encompasses three phases, namely a planning, development and implementation phase. The work of several scholars is combined to create one roadmapping framework. Specific notion should be given to the study of Phaal et al. (2004a), which was used as the main source for the development phase, and the work of Gerdsri et al. (2010), which was the main source for the planning and implementation phase.

The technology roadmapping process was conceptualized in the introduction as: "A technology roadmapping process is a structured set of activities aimed at integrating short- and long-term knowledge from the market, products, services and technology, leading to a map of unfolding evolution of technologies and product or services that implement them to ensure that the required technologies will be available when needed". Although this increases the understanding of the concept it is still interpreted rather broadly. This is illustrated in following paragraph by the fact that several approaches exist regarding the technology roadmapping process. Thereafter, an elaboration of the technology roadmapping process is given. Figure 6 shows a basic overview of the phases.

Figure 6: Phases of the technology roadmapping process

3.2.1 Multiple approaches to a technology roadmapping process

The first decision that needs to be made regards the ownership of the technology roadmapping process. Cosner et al. (2007) explain that there are three possible approaches in this light. The first is the central process, where an enterprise team is responsible for the roadmapping process. This team meets with stakeholders to obtain and understand data within the firm. Based on the gathered information the team creates a roadmap which is then distributed to the business units. The approach makes sure that roadmaps are created with consistent content and format. Furthermore, it can be used to create summary roadmaps of the different business units. Cosner et al. (2007) emphasize that this approach maximizes the likelihood of finding synergies across the different roadmaps. The second approach is the distributed approach. In this method the roadmaps are

created by the individual business-units. The content owners of the business units are provided with guidelines by the enterprise team how the integration should be handled. The workshop approach is the third method which encompasses collaborative sessions with business-unit content owners to create roadmaps. The sessions are lead by the enterprise team. This last approach has been adopted in this thesis because this method has proven to be effective (Phaal et al., 2004b; Gerdsri et al., 2010). The main advantage is that participants can discuss the content of the roadmap with multiple important stakeholders and reach consensus regarding the prioritization.

Another choice needs to be made regarding the method of obtaining data. Kostoff & Schaller (2001) have identified two different methods. The first is the expert-based approach in which a team of experts from different fields are brought together to develop a roadmap. The second approach is named the computer-based approach and uses large databases that describe science, technology, engineering, and finalized products which can be used for analysis (Kostoff & Schaller, 2001). The aim is to quantify all the data to a standard measure whereby nodes and links can be created through which a network is constructed. This approach has mainly been used in science and technology disciplines because databases tend to contain valuable information on these topics. However, the computer-based approach is still in its infancy, due to the only recent availability of large databases and computer based methods to process the information (Kostoff & Schaller, 2001). This thesis has adopted the expert-based approach as the computer-based approach is still rather experimental and no large databases were available.

3.2.2 Planning phase

The first phase of the technology roadmapping process is the planning phase (figure 7). The aim of this phase is to gather essential information which is needed in later stages of the roadmapping process (Gerdsri et al., 2010). Several scholars created guidelines of what steps need to be followed in this phase (Phaal et al., 2004a; Cosner et al., 2007; Gerdsri et al., 2010). These steps were compared (see appendix E) and it became apparent that there are three main steps in the planning phase.

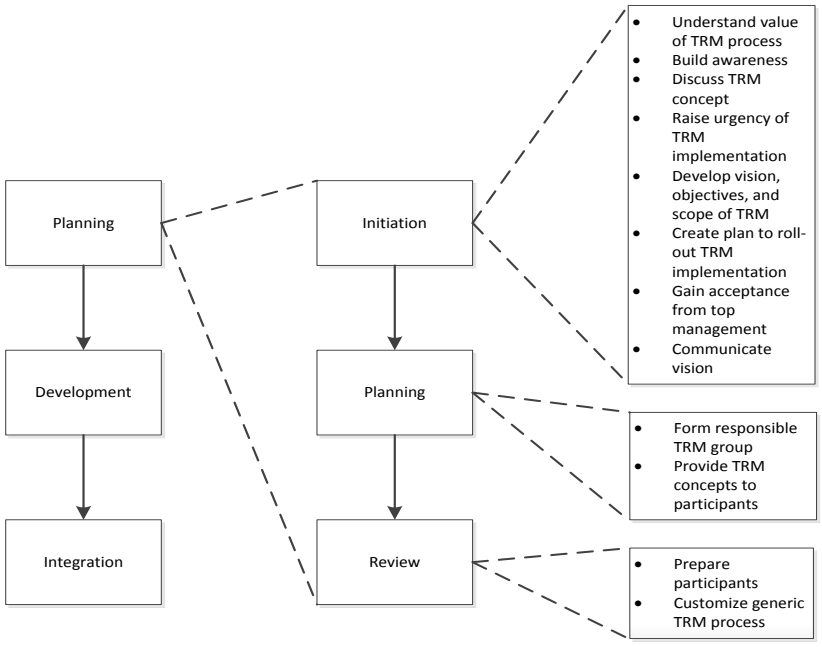

Figure 7: Planning phase of a TRM (based on guideline of Gerdsri et al., 2010)

First, the technology roadmapping process should be initiated. The understanding, awareness and urgency of implementing a technology roadmapping process needs to be acknowledged and understood. In addition, top management support needs to be obtained so the process is fully supported (Gerdsri et al., 2010). Once this has been established the scope, aim and focus of the technology roadmapping process have to be determined. By defining the focus of the research it becomes clear what phenomena need to be considered, while the scope of the research refers to the range of factors included in the research. Additionally, it is recommended that the objectives for the process of the company are clearly articulated. By operationalizing the objectives of the company it becomes clear for the researcher what purpose the roadmap should meet. Besides providing guidance this is useful for judging the success of the process in the end (Gerdsri et al., 2010). The team guiding the roadmapping process should also be identified at this stage. This can either be a champion or a team which is empowered and has the responsibility of initiating and managing the process (Cosner et al., 2007).

The second step encompasses a literature review. The literature review includes both a methodology and content review. The methodology review is necessary in order to prepare the team with understanding the TRM process and to manage it properly (Gerdsri et al., 2010). Kostoff et al. (2004) add that during this phase a content literature-based discovery process should take place. Relevant information should be gathered to support the process. An appropriate time frame and relevant layers need to be identified. The layers act as the different subjects of the workshops.

The third step is labeled as the workshop planning step. Based on the first roadmap architecture appropriate participants can be identified for each workshop (Phaal & Muller, 2009; Gerdsri et al., 2010). Participants should have diverse and relevant knowledge as this increases the chance of success of a roadmap (Kostoff et al., 2004). In this respect Phaal et al. (2004a) point out that these participants should have different perspectives such as internal vs. external employees or the production vs. marketing department. By including both technical and commercial participant these points of view are also incorporated into the roadmap (Phaal & Muller, 2009). Additionally, continuity of participants throughout the process is recommended, particularly for a core group (Phaal et al., 2004a). Once the participants have been identified their agenda's can be compared to plan the workshops.

3.2.3 Workshop phase

The second phase is the workshop phase. Gerdsri et al. (2010) state that the main emphasis of this stage is to collect and analyze data. A series of workshops is organized whereby internal and external experts are invited to analyze data and present results in the form of a roadmap. The experts are expected to work together and thereby share their knowledge to develop a company roadmap. The identified layers in the roadmap architecture each act as a subject of a workshop. The standard T-plan approach of Phaal et al. (2003) describes what the outcome of a workshop should be, however detailed guidelines regarding the methodology for the workshop were not available. An overview of the standard T-plan can be found in figure 8.

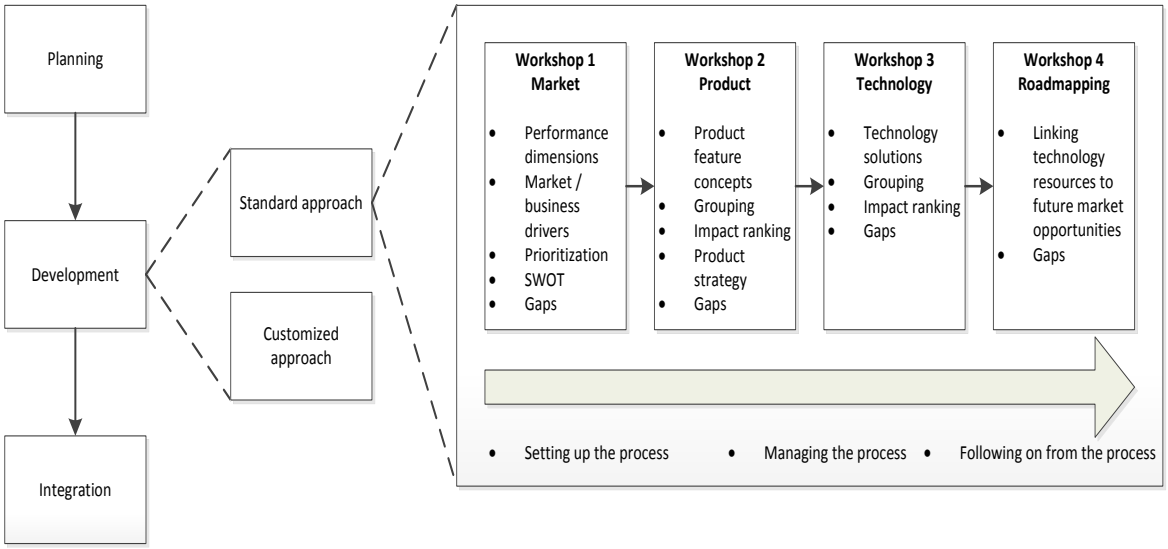

Figure 8: Development phase of a standard T-Plan (Phaal et al. 2003)

3.2.3.1 Market workshop

The workshop series start with a market workshop which has the aim to create a set of prioritized market and business drivers for the future. It is encouraged to identify internal (e.g. growth of the firm) and external (e.g. legislation) drivers. The first step of the process is to establish a set of performance dimensions, for example the reliability and speed of a product. This is a good starting point because the drivers can be easily identified and they relate directly to the product. The second step is the identification of market and business drivers. These drivers should be grouped and prioritized for every market segment. The third step is to identify gaps in the market, an example is the identification of certain customer needs which are not yet satisfied. The main outcome of this workshop is a set of prioritized market and business drivers (Phaal et al., 2004a).

3.2.3.2 Product workshop

The second workshop of the standard T-plan is the product workshop. The aim of this workshop is to develop a set of product feature concepts that could satisfy the market and business drivers that were identified in the previous workshop. The first step of is the identification of product features (e.g. reliability and robustness). This leads to a list of features which are linked to the prioritized market and business drivers in the second step. This can be done with the use of linkage grids. Linkage grids display the prioritized drivers on the horizontal axis and product features on the vertical axis which allows linking them. The third step is to group the product feature concepts and rank their impact for each market and business driver. Thereby an overview of combined product features is created for a specific driver. The fourth step is to brainstorm about alternative product strategies which could be used to respond to market and business drivers. This is basically identifying gaps in the product features (Phaal et al., 2004a).

3.2.3.3 Technology workshop

The third workshop is focused on technologies. The aim is to identify possible technological solutions that could develop a product feature. First, participants should brainstorm about possible technological solutions for the different product features. It is encouraged to go beyond technologies which are currently within the company and to broaden the technological perspective. This leads to the identification of gaps in the technological area. Second, the solutions should be grouped into

technical areas and subsequently be linked to the product features of the previous workshop. This is again done with the help of a linkage grid. Third, the impact of technological areas is ranked based on the desired product features (Phaal et al., 2004a).

3.2.3.4 Roadmapping workshop

The roadmapping workshop is the fourth and last in the standard approach. This has the aim to produce a roadmap based on the information of the previous workshops. The first step is to determine the format of the roadmap. This encompasses several elements such as time scales, levels and strategy. This format is used for the second step where key milestones are identified, product evolution is plotted and technological programs are identified. Hereby linkages are created between the different layers. The third step encompasses the scheduling of the activities which need to be initiated. This depends on the marketing department to see what is needed in the market, and the technical department to see what is feasible from their perspective (Phaal et al., 2004a).

3.2.3.5 Validation

After each single workshop Cosner et al. (2007) advise to validate the content of the workshop. This is the owner's responsibility. If a roadmap does not reflect the true needs or trends, then using the roadmap is worse than having never created it (Cosner et al., 2007). Wells et al. (2004) validate their roadmap by incorporating a research and validation stage. Although they do not thoroughly explain what this exactly includes, it becomes clear that within this stage participants are provided the opportunity to step back from the workshop and consider the map content and its key messages. A method to validate the content after the workshop is to conduct an interview with an expert.

3.2.4 Integration phase

The third phase is the integration of the roadmapping process within the firm. Several scholars state that this phase aims to integrate the roadmapping process into ongoing business operations thereby becoming part of the company's overall business processes (Cosner et al., 2007; Gerdsri et al., 2010). In the integration phase Gerdsri et al.'s (2010) guidelines will be used to determine the steps that need to be taken in this phase. Figure 9 gives an overview of the steps that need to be taken.

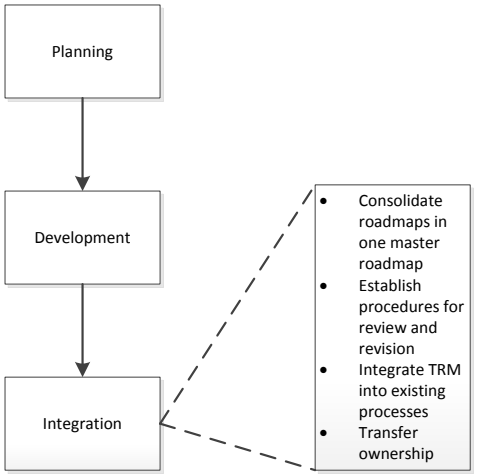

Figure 9: Integration phase of a TRM process

The first step in the integration process is the creation of a master roadmap when multiple roadmaps have been designed (Gerdsri et al., 2010). When the roadmaps have been finalized it should be integrated into different roadmaps. Thereby a family of roadmaps is created. This is not limited to

one product or service, but shows a bigger picture of ongoing processes within a firm. This helps to create an overview of the entire process. The second step is the creation of procedures so that technology roadmapping becomes an ongoing process. In order to keep it alive it should be kept up to date. How often the roadmap should be revised depends upon the product life cycles (Cosner et al., 2007). Therefore they suggest that revisions should take place at least once a year, but in fast moving sectors it should be done more often.

Integrating the roadmapping process into ongoing processes is the third step. Phaal et al. (2004b) state that the integration of a roadmap should be appropriate in terms of the company's needs and circumstances. In this light Kappel (2001) identified two different tactics of introducing roadmaps within a firm. The first approach is the diffusion tactic, which assumes that roadmapping belongs everywhere in the entire organization. The second approach involves selective introduction into the most important areas of the business. Thereby the assumption is made that roadmapping is not needed throughout the entire organization, but can be applied within a specific context. It is important to determine in what way roadmapping should be used within a company because it affects the way it is integrated into ongoing processes. The fourth and last step encompasses the transfer of ownership of managing the roadmapping process. It is vital to assign responsibilities to employees for regularly maintaining and updating the roadmap.

In order to integrate a roadmap-based planning approach proper change management techniques are required. Various departments need to work together which can be difficult to achieve. Furthermore top management support needs to be gained to implement changes need for successful technology roadmapping. In order to achieve support for the change process the process should include clearly defined objectives and metrics to measure overall success (Cosner et al., 2007). By using a bottom-up approach a foundation for support is created for the roadmapping process. In order to implement roadmapping effectively, Cosner et al. (2007) point out that it is best to start with simple processes and demonstrate the value of these projects by creating success stories which create a base of support. Therefore it is recommended to start with smaller product lines where information is available and the team is motivated of getting the process going. Gerdsri et al. (2010) explain that using well-known change models helps an organization with the transition to integrate roadmapping into the ongoing processes.

3.2.5 Customization

Depending on the characteristics of the firm and the purpose of the roadmap a standard roadmap might not fit the company. Therefore the standard approach should be adapted and modified to the specific situation of the firm. This is in essence agreed upon by several scholars (Groenveld, 1997; Phaal et al., 2004b; Lee & Park, 2005; Geum et al., 2011b). The two latter scholars have pointed out factors that need to be taken into account when customizing the roadmapping process. Lee & Park (2005) take a perspective of modularization. This means that a practitioner can choose the most relevant layers from a set of given generic layers. However, Lee & Park (2005) focus their roadmaps exclusively on products and do not have any standard layers focused on services. Therefore this approach is not useful for this thesis. The approach of Phaal et al. (2004b) will be followed.

Whether the process should be customized is determined in the planning phase. Phaal et al. (2004b) explain that it depends on the scope, focus, aims and resources. These steps are all taken in the planning phase, so if it is necessary to adapt the process or architecture it will become evident there.

Customization can be applied to both the macro and micro processes. Customization of the macro process refers to how the overall process will work, in terms of a series of stages that lead toward the end goal (Phaal et al., 2004b). When this is necessary, on the one hand some layers of standard approach might be redundant, while on the other hand additional layers might be needed to complete the roadmap. Therefore it is essential to understand the context of the roadmap and to adapt the process. There is no unique or best way of structuring the layers and sub-layers in the customization process. Often a number of possible strategies for the roadmap architecture are identified (Phaal & Muller, 2009). Generally, a layering strategy is adopted whereby a high degree of de-coupling between the different layers is possible, meaning that the layers can be differentiated from each other. Each layer should evolve over time, thereby providing a route to the future. Phaal & Muller (2009) imagine that if a roadmap tells a story then each layer or sub-layer represents a chapter of the story. The micro-process addresses how to design a detailed process (Phaal et al., 2004b). More specifically, it addresses the agenda of the workshops. A logical process should be taken into account again because the output of one activity is the input for another. Depending on the available resources the agenda will be created.

Although several scholars have articulated the importance of customization, and the above mentioned general tips and advice is helpful, a step for step guideline how to customize the roadmapping process is not available. Phaal et al. (2004b) state that attention should be paid to customizing the process and the architecture, but it does not become clear how this should be done.

3.2.6 Conclusion

This paragraph makes it clear that several steps need to be fulfilled in order to successfully implement a TRM process within a firm. In short these are:

- A choice regarding the ownership of the TRM process should be made. The central process, the distributed approach and the workshop approach can be chosen.
- The data of the roadmap can be obtained via an expert-based approach and a computer based approach.
- The initiation of the TRM process consists out of multiple steps. The most important are creating awareness of the value, obtain support for the TRM process, the development of a TRM team and customize the process to the specific situation of the firm.
- The development of a roadmap is done through the elaboration of multiple layers and subsequently linking them. These layers are identified during the customization.
- If an organization wants that TRM becomes an ongoing process within the firm the implementation phase is important to consider. The most important steps are the development of procedures for review, the integration into existing processes and to transfer the ownership of the TRM process.
- Choosing a generic TRM framework as a starting point of the process mainly depends upon the purpose of the TRM process.
- Customization of the architecture and process design should be done in the preparation phase. General tips and hints are available for the customization process, but a detailed step-for-step guide how to adapt the process is missing.

3.3 Current state-of-the-art in technology-service roadmapping

This sections aims at describing how the current roadmaps for service oriented firms have been designed and what is important to consider for developing a TRM process within such a firm.

3.3.1 Emergence of the service literature

Traditionally the manufacturing sector has dominated theoretical and empirical literature on innovation and technology management as this sector was the major producer and user of technology (Evangelista, 2000; Drejer, 2004; Kindström & Kowalkowski, 2009). Research within the manufacturing sector has contributed to the understanding of how innovative activities take place, what factors affect a firms' innovativeness, and how technological paradigms differ within firms and industries (Evangelista, 2000). Over the last two decades a shift of tangible toward intangible investments has gained attention in academics thereby gaining increased importance as a research field (Evangelista, 2000). The emergence of ICT and the increasing awareness of the power of human resources have increased the role of services. Despite the increasing research on innovation in the service sector, service innovation concepts are not yet well established. Gallouj & Weinstein (1997) point out that this is on the one hand caused by the historical focus on technological innovation in manufacturing firms and on the other hand the 'fuzzy' nature of services which makes it difficult to measure them.

Firms are not merely using services as an addition to products, but value services as a core business nowadays (Kindström & Kowalkowski, 2009). This paradigm shift is reflected in a change of the innovation process moving towards a learning process that generates or acquires new knowledge whereby knowledge-intensive based services are gaining increasing attention (van Riel et al., 2004). It becomes clear that structured acquisition of information with respect to developments in technology and customer requirements can make a substantial difference in the success of high-technology service innovations. A focus on the structural collection of technological intelligence and trends in consumer needs is recommended as these activities increase the effectiveness of the speed and quality of the new service development process.

3.3.2 The rise of the synthesis school of thought

Studies within service innovation and new service development fields point out that services have been interpreted differently over time (Gallouj, 1998; Hipp & Grupp, 2005; Sundbo et al., 2007). This implicates a fragmented landscape regarding the view on services exists. One of the first explanations was the technologist perspective which proposed that the innovation cycle starts with a process innovation which subsequently leads to new services (Abernathy & Utterback, 1978; Barras, 1990; Linton & Walsh, 2008). Related to this stream is the assimilation approach. Scholars of this stream propose that theories and concepts which are developed in manufacturing field can be transferred to the service innovation field (De Vries, 2006; Nijssen et al., 2006; Howells, 2006). Like the former school they also believe that the manufacturing and service fields show similarities with respect to the basic dimensions of the innovation process (Sirilli & Evangelista, 1998). By applying their focus on technological innovations other developments, such as organizational innovations, are ignored (Drejer, 2004). Therefore it is described as being too limited to cover the entire field of service innovation (Drejer, 2004). A third stream, the demarcation approach, opposes the assimilation point of view. The primary focus of this stream is not to compare service innovations directly to manufacturing innovations, but rather to study service innovations separately because their distinct features, such as the intangibility, involvement of customers, simultaneity, and

heterogeneity make it difficult to transfer them (Den Hertog, 2000; Gallouj, 2000; Drejer, 2004). In the last decade a new stream of research raised, namely the synthesis approach. This approach has gained increasing attention in the scientific literature (Droege et al., 2009). The focus of this stream has been on bringing manufacturing and services research together instead of studying them as separate fields (Gallouj & Weinstein, 1997; Coombs & Miles, 2000; Nightingdale, 2003). The stream takes the blurring boundaries between the service and manufacturing fields into account, and thus takes on a perspective that is not bound to the traditional service or manufacturing taxonomies (Drejer, 2004).

3.3.3 Product-service integration

A consequence of the rise of the synthesis school of thought is the development of the product-service system (PSS). Where characteristics of products and service have been studied separately in the past, the aim of this concept is merge them into one system (White et al., 1999; Manzini & Vezzoli; 2003). Goedkoop et al. (1999, p. 111) describe the product-service system as "a system of products, services, networks of 'players' and supporting infrastructure that continuously strives to be competitive, satisfy customer needs and have a lower environmental impact than traditional business models".

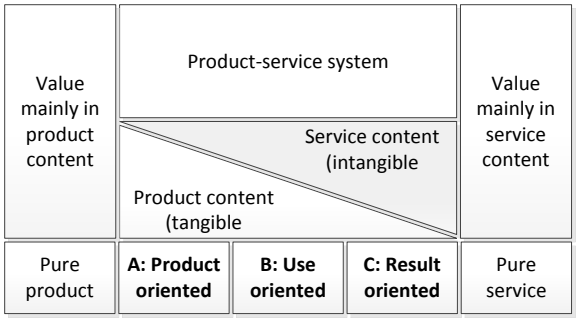

Figure 10: PSS model of Baines et al. (2007)

As illustrated in figure 10 the starting point of the integration can be both the product as well as the service. Including services into products has lead to the term of *servitization* of products, while services have *productized* (Baines et al., 2007). *Servitization* is the development of material based products to a service system in which the material component is inseparable. *Productization* is the evolution of a service which includes a product or new service component marketed as a product (Baines, 2007). Within PSS the ownership of assets is not transferred to the customer. The assets remain property of the provider. Further differentiation is made between three types of PSS.

- *Product-oriented PSS* refers to products which are sold in a traditional manner with the addition of specific services such maintenance and customer help.
- *Use-oriented PSS* is captured as the sale of a product which can be used but is not owned by the customer. An example is the leasing of a car.
- *Result-oriented PSS* encompasses the sale of a result or a capability instead of a product. A mix of services is offered and the customer only pays for the end result.

Benefits of integrating products and services for customers are the increase in value through enhanced customization, higher quality, better suitability to customer needs and moving administrative and monitoring tasks from the customer back to the deliverer. From a firm

perspective the main benefit of PSS is an improvement in total value for the customer by an increasing amount of service elements (Baines et al., 2007). The increase in total value enhances the competitive advantage of the provider. To capture the full increase in competitive advantage service elements should not be easy to copy.

3.3.4 Technology roadmapping in the service industry

Services often have a complex network of enabling services, products and technologies (Gann & Salter, 2000). Therefore specific service roadmaps have been developed. Before explaining how the concept of PSS has been implemented within technology roadmapping, a brief overview is presented regarding the development of technology roadmapping within the service industry. The first step of technology service roadmapping in the academic world was made by adding a service layer to the traditional roadmaps (Kameoka et al., 2006; Nakamura et al., 2006; Fenwick et al., 2009). In other cases product or market layers appeared which included service contents and thereby replaced the product layer (An et al., 2008; Cho & Lee, 2011). Figure 11 shows an overview of the first steps in the academic world by adding an additional service layer.

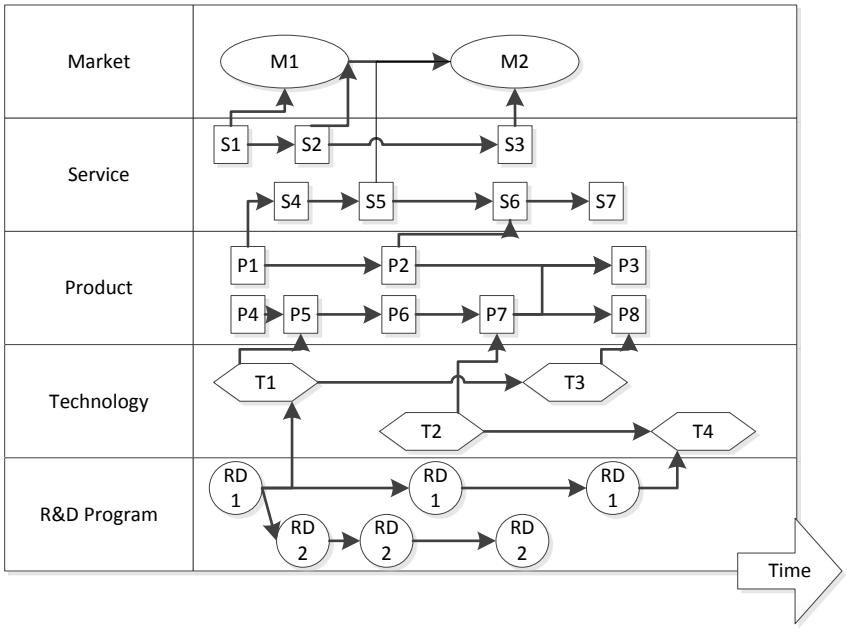

Figure 11: First service roadmap of Kameoka et al. 2006

Despite the limited amount academic research TRM is most of all a practical method which is adopted by firms. Therefore Cho & Lee (2011) conducted an empirical review to obtain a better understanding what types of roadmaps are present within the service industry. In total 761 roadmaps were retrieved of which 93 met the criteria of having time-based layers. The first roadmap they distinguish is the *product-focused technology roadmap*. This type is developed in an industry where product offering is critical in providing service (Cho & Lee, 2011). This type of roadmap is based upon the assumption that products and technologies are essential and change rapidly, while the characteristics of services remain mostly unchanged. Thus, product and technology planning is relatively more important than service planning. Secondly, *service-focused technology roadmaps* are designed specifically for services. In this case the purpose is to create a service in order to respond to market needs. Thirdly, the *product-service integration roadmap* aims to integrate planning of products and services. Cho & Lee (2011) illustrate this type of roadmap by the use of the mobile

communication industry. Both hardware and software of mobile phones are crucial to delivering mobile communications services successfully. Fourthly, *technology-driven service roadmaps* start from technology planning to find new service opportunities based on technology development. This can be considered as a pure technology push roadmap, as new services come from technology innovation. Finally, a *product-service technology roadmap* includes all three elements of products, services, and technology. An example was presented from the e-business logistics industry. The industry is based on the internet, but next to services also products and technologies are important planning elements.

3.3.5 The integration of PSS into technology roadmapping

The last step in the academic research has been made recently. Several scholars have attempted to create product-service integrated roadmaps (An et al, 2008; Geum et al., 2010; Geum & Park, 2011; Geum et al., 2011a). Geum et al. (2011a) have attempted to obtain an in-depth understanding of roadmaps which Cho & Lee (2011) had classified as *product-service integration roadmaps*. The aim of these roadmaps is to integrate related services and products into one roadmap because single products are no longer sufficient to satisfy customer needs (Geum et al., 2011a). In the view of Geum et al. (2011a) technology plays a crucial role for the integration of products and services. Products, services and technology are separate layers and the hierarchy is dependent upon the sort of role technology plays in the relationship. Technology can act as the *enabler*, *mediator* and *facilitator* of the integration.

- *Technology as the enabler* indicates that the integration of products and services cannot be realized without the use of technology. In this case technology provides the direct means for integration. An example of this is the customization of computers which you can order on the internet. Nowadays it is possible to choose the modules you want in your computer on the internet. The service of modularization is very closely related to the product which is the computer itself. Geum et al. (2011a) indicate that this is the integration of products and services. The service of modularization has been enabled by the development of the internet, which is the technology in this case.
- *Technology as the mediator* refers to the case when technology is the intermediary for the integration of products and services. Technology is first applied to a product or a service and the integration is then created by the embedded technology within the products and services. An example of this is the development of microchips within smartphones. The development of this technology enabled the creation of smartphones as a product. Subsequently, smartphones can be used for internet banking as a service. In this case the development evolves in a chain.
- *Technology as the facilitator* means that it has no direct effect on the integration of products and services, but additional help is provided to foster the integration. In this case a product leads to a service, so a smartphone leads to location independent banking as a service. The technology here is the development of the internet. This does not have a direct effect on the development of a smartphone, but it is an additional help which enables the independent online banking.

3.3.6 Conclusion

As the aim of this thesis is to implement a TRM process within a service-oriented firm it is evident to consult available academic literature on this topic. It became clear that technology roadmapping

within service-oriented firms is relatively new in academics. The first papers have been published around mid 2000's. However, services have become more important and are not used merely as an addition to the product but valued as a core part of a business. Therefore it is important to consider TRM within service-oriented firms as these firms need to determine how to effectively manage technologies. The first service roadmaps have been developed by adding a service layer to the existing architecture of a roadmap. Subsequent service roadmaps have taken the fading boundaries of products and services into account by implementing the concept of product-service integration into roadmaps. However, more research is necessary to obtain a better understanding of the TRM process within service-oriented firms.

4 Findings

This chapter contains the findings of the thesis. In order to answer the central research question, the four aspects that affect the suitability of the TRM process will be presented. The first section deals with choosing the variables that lead to customizing the architecture and thereafter how these variables affect the architecture of the roadmap. The roadmap architecture is mainly focused at adapting the layers of the roadmap. Subsequently, the findings of the design of the TRM process are presented. This encompasses the detailed design of the workshops, while the last paragraph gives an overview of the success of the process.

4.1 Customization of the TRM architecture

In absence of customization methods this paragraph first presents the customization method that has been used to identify the variables that affected the customization of the architecture. The following paragraphs first explain why a certain variable led to a customization. This relates to sub-question 1. Subsequently it is explained how the TRM architecture was adapted according to these identified characteristics. This has the aim to answer sub-question 2.

4.1.1 Method of customization

It is widely accepted within the technology roadmapping literature that customization is necessary (Groenveld, 1997; Phaal et al., 2004b; Lee & Park, 2005). However, exact methods how to spot the variables that demand customization were missing. Therefore a variety of information sources were used to customize the TRM process. First, secondary sources, mainly internal company documents, gave valuable information of the strategy, structures and possible relevant participants for the workshops. Second, informal daily routines and formal meetings were observed. This was valuable in order to get an idea of how the organization works and to what extent knowledge spillovers are present within the firm. Third, academic literature was used to find variables which possibly could affect the TRM process. Fourth, meetings with the TRM team and other stakeholders were held. These meetings were conducted to obtain ideas of these stakeholders and to validate the information gathered from the secondary data, observations and the literature review. A combination of these methods led to the identification of the purpose of the TRM process and the identification of the characteristics which influenced the TRM process. Figure 12 illustrates the method that has been used.

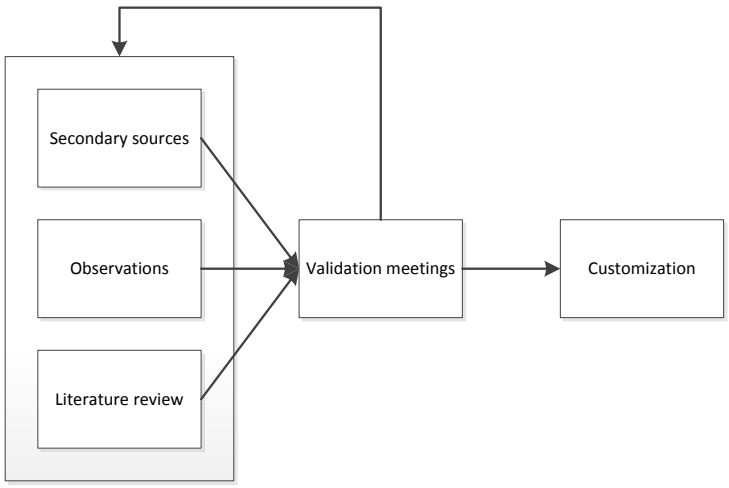

Figure 12: Customization model

4.1.2 Purpose

The first variable that has influenced the customization of TRM architecture is the purpose of the process. In order to determine the exact purpose of the TRM process two separate interviews with the head of the strategy department and with the head of the product management department were held. For the head of the strategy department the objective was twofold as "it should enhance decision making both on a strategic and product level". For the head to the product management department the main goal was to "develop a guideline for creating new or improving current services by incorporating technology and market foresight". Based on these two statements the main objective for the entire TRM process has been captured as "the development of a technology roadmapping process which integrates the new service development process with technology and market foresight".

Several decisions were made within the TRM team regarding the focus and application of the roadmapping process. Within the organization a differentiation is made between *run the business* and *change the business* projects. *Run the business* is focused on optimizing the current products and services, hereby one should think of cost reduction and lower run-through times. *Change the business* projects aim to develop new products and services. A large project which had the focus of *run the business* had recently finished within TC. Therefore a lot of incremental projects had been identified, but there was a lack of ideas that go beyond the current offerings. This roadmapping process had the aim to focus on *change the business* and thereby looking for new to firm product-service features and technologies. Additionally, the product management department was established five months before the initiation of this TRM process. A roadmapping process had been implemented before, but this was a pure product planning roadmap, without explicit links to technologies or strategy. Therefore the TRM process as described previously was new to the firm. Cosner et al. (2007) state that it seemed best to start with a simple TRM process to demonstrate the value and to create a success story. Following this advice it was decided to implement the TRM process for one of the product-families of TC, namely for manual toll collection (MV).

Based on the above described objective of the roadmapping process it was clear that the roadmap architecture should combine market, product/service and technological developments. These layers were chosen as the core of the TRM framework. Kappel (2001) calls such a roadmap a product-technology roadmap, while Phaal et al. (2004a) refer to it as a product-technology planning roadmap.

4.1.3 Product-service system integration

The second identified variable is the product-service system integration. Background information regarding this concept can be found in paragraphs 3.3.2 and 3.3.3. The synthesis view on the integration of products and services, whereby products contain elements of services and vice versa, was found in TC. The head of the product management department explained that "concepts of products and services are used interchangeably". This is not a strange development within service companies. Oke (2007) explains that terms such as "service product innovations" and "product innovations" are both used to explain a particular set of innovations within a service company. These innovations are related to the core offerings of service companies instead of strictly referring to a product or a service (Gadrey et al., 1995).

Although company documents do describe different definitions for products and services these are not strictly used within the company. It would have been difficult to implement the PSS concept as

Geum et al. (2011a) have adopted it because they clearly differentiate between products and services. This company was not used to the distinction in those terms, therefore instead of using two separate layers these have been combined into the product-service layer as this fitted most with the current patterns of thought within the firm. In terms of the standard T-Plan of Phaal et al. (2003) the product layer was substituted with a combined product-service layer. The focus during the product-service layer was on the core offerings, of both products and services, as Oke (2007) explained.

4.1.4 New service development

The third relevant variable is the presence of a new service development process at TC. A clear distinction exists between the offering of a service company and a manufacturing firm. Menor et al. (2002) articulate that the output between new product development (NPD) and new service development (NSD) differs. The output of a NPD process is a physical entity, where a physical entity was defined as a system of parts that must work together in a physical product as a whole. In most cases the output of a NSD process is a service delivery process (Fitzsimmons & Fitzsimmons, 2001; Johnson et al., 2000). This consists of personnel, materials, information flows, facilitating goods, supporting information technology and physical facilities which need to work together in order to act as a functioning service delivery process (Menor et al., 2002). This shows that services have *productized* as they include facilitating goods and physical facilities. A unique issue which is not raised in the NPD literature is that the front and back-ends of services have different objectives but still must function together as an integrated whole to provide the composite service (Menor et al., 2002).

This indicates that the front-end of a service is highly connected and dependent on the back-end of the service. Therefore the current structures and infrastructure of these services should be taken into account with NSD. Validation interviews confirmed that the current structures and infrastructures are very important aspects to take into account when thinking of new service developments. From the observations can be drawn that “time can be invested in exploring to what extent a feature changes the current system that TC has in place, and whether a new part of the system needs to be implemented or adapted. This can be valuable to know for the government as they largely decide upon the investments”. Therefore it was decided to insert a fourth layer which was named the systems layer. This should give the organization a view to what extent the current structures and architecture are affected by new technologies.

4.1.5 Contracting out

The fourth and last variable relates to the fact that the service that TC offers is legitimated by a contract drawn up with the government of Germany. This contract describes in detail which obligations and duties TC has. However, due to the restrictions within the contract the company is limited in their actions that go beyond the features of the contract. Long negotiation times precede the decision making whether a product or service feature is implemented. During the contract time the company holds an artificial monopoly position. Literature studying the effect of market competition on innovation performance is largely present. Although there is no unanimous consensus on this matter, empirical evidence in a variety of industries found that the inverted U-shape leads to the highest innovation performance (Aghion et al., 2005). This means that there is an optimal number of firms competing in a market. For this study it should be taken into account that the monopoly position of the company is not a natural one, the market is defined by the contract and there might be competitors who want to enter the market once the contract has expired (Domberger & Jensen, 1997; Hefetz & Warner, 2011). With respect to monopolies created by contracts, research

shows that such a contract tends to create a short-term focus on the deliverables of the contract at the expense of longer-term goals (Autor & Houseman, 2005). In addition, Lee et al. (2009) find in their empirical study that regulations limit service innovativeness. In short, a defined contract tells a firm to provide a certain service and the provider of the service just does this.

Observations and interviews indicated that it was difficult for the company to think beyond the contract and that the acceptance of a feature which a service company wants to implement needs to be obtained upfront. The external consultant explained: “The main problem with the contract and all contracts, all relationships between a service company and their customers are that you have got a long lasting contract that ends at some point in the future. For us this point in the future is relatively close. You always want to achieve two goals at the same time. You want to fulfil the contract as it is today, without changing it. [...] At the same time you want to optimize your service, by adding new features or skipping features that are not helpful. Therefore you only have a few points where you can make larger adjustments to your services. [...] You have to create the contract in such a way that you are flexible enough to make some changes and to implement new features. That is very difficult”. In addition he explained that “you can’t just add a feature and see how the market reacts, like a normal manufacturing company could do it. I just do it and then I will see if they like it or not, I can always change it or take it back. But you always need the acceptance of your customers upfront as a service company.”

The current contract is always taken into account which implicates a short-term focus which has the potential to limit the ideas for the future. However, on the other hand the firm needs to have a clear idea of features that they want to implement because the customer has to accept these features during contract renewals before the implementation as they pay for it. For the TRM architecture this means that a distinction in sub-layers is made within the product-service workshop. One sub-layer of features reflects the needs of the user while the other sub-layer integrates the view of the customer.

4.1.6 Conclusion of the TRM architecture customization

Concrete customization methods were not present within the technology roadmapping literature. Therefore a customization model which combines multiple data collection methods has been developed. The application of this model led to the identification of four variables that have influenced the architectural customization process within TC namely the purpose of the TRM process, product-service integration, new service development and contracting out. Based on these variables the layers of the TRM process were adapted. It should be noted here that a standard timeframe of ten years has been chosen for the architecture. No reasons were found to shorten or lengthen the standard timeframe of ten years. Figure 13 illustrates the final outcome of the customization process.

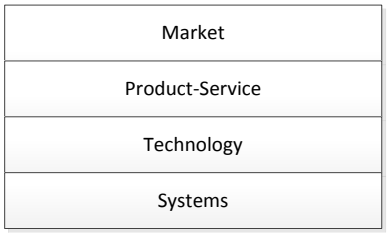

Figure 13: Final layers of the customized TRM process

4.2 Customization of the process design

Whereas the customization of the architecture refers to the adapting the layers of the TRM process, changing the process design relates to the design of the specific workshops and their preparation. As the workshops were carefully prepared the findings of the planning phase are presented first. The findings of the development phase are given next, where each workshop has its own sub-paragraph. This encompasses the customization of the process design based on the chosen architecture, therefore this relates to sub-question 3. Lastly, the findings of the success of the process are shown.

4.2.1 Planning phase

The entire TRM process began with an extensive literature review which resulted into the creation of the theoretical framework presented earlier. In order to introduce TRM within the firm a team was formed which customized the process as explained previously. The researcher was joined by an external consultant and a new to the firm product manager. The role of the researcher changed hereby more into a methodological consultant. The product manager took over the role of mediator during the workshops, while the external consultant had a supporting role of adapting the TRM process to the conditions of the firm. Due to the creation of this team the group dynamics changed leading to a decrease of control for the researcher. This is a well-known disadvantage of applying action research. The new group members did not have theoretical nor practical experience with TRM. Therefore the only expertise was the theoretical understanding of the researcher.

The expertise of the new group members came into place during the customization of the process design. A series of seventeen meetings was held in order to explain the TRM process and subsequently to adapt the process to context of TC. Looking back the external consultant explained that “they were very important because of two main factors. One, it was the very first time that we conducted this workshop approach in the firm. We had to adapt it to the reality of the firm. And number two, both you and the product manager were new to the firm and don’t know the systems, processes and backgrounds”. The product manager agreed that these meetings were needed to adapt the process. He explained that “the difficulty was that it was a new process for the company, new process for me and maybe for you. So a lot of the meetings were just to get the same idea about what you want to do. If you know what you want to do, you can at least skip 2/3 of the meetings. But, I think for the process it was necessary because we had to explain to ourselves what we wanted to do, what is the goal, what are the definitions of special items. Therefore I don’t think this has been a waste of time”.

4.2.2 Development phase

This section aims at presenting the findings of each single workshop. Every section begins with some information regarding which and how many participants were present. Then the agenda is presented to create transparency and it is explained to what extent the agenda was adapted compared to the T-Plan. The key successes and failures of the workshop are presented next, while the last section encompasses an elaboration of the validation of the workshop.

4.2.2.1 Market workshop

The market workshop was the first one on the agenda. A total of six participants were present who were from the product management and strategy department. The goal of this workshop was to identify a set of prioritized market and business drivers. Table 7 shows an overview of the agenda for this workshop.

Block	Time	Method
Introduction	15 min	
Presentation performance dimensions & drivers	20 min	
Brainstorming drivers	30 min	Brainwriting 635 method
Discussion driver + identification of problems + grouping	90 min	Nominal Grouping Technique
Prioritization	15 min	Individual
Closing	10 min	

Table 7: Agenda of the market workshop

The agenda of the standard T-Plan was used for a large extent for designing the agenda of the workshop. What deviated was that the performance dimensions were prepared and given before the workshop started. The workshops that have been implemented at TC were shorter than normally, therefore it was decided to skip the SWOT analysis and focus the design of the workshop at finding the relevant drivers and their respective priorities. The nominal grouping technique and brainwriting methods had been added as methods to brainstorm about market drivers and to discuss problems. During the brainwriting all participants ceased talking and wrote down their ideas silently as Thompson (2003) explained. This was done in six rounds whereby every participant had the task of writing at least three ideas down every five minutes. The nominal grouping technique is an extension of the brainwriting method by the addition of a discussion, evaluation and prioritization of the ideas. Aside from the methods during all workshop participants were encouraged to go beyond the current specification of the contract to identify possible features. As explained in section 4.1.5 the contract implicates a short-term orientation on the current contract. Therefore it was articulated to the participants that the roadmap covers a period of ten years and that they should not constrain themselves during brainstorming sessions due to the limitations of the current contract. This does not only count for this specific workshop, but for all of them.

The following part describes the key successes and failures of the workshop. The introduction raised a lot of discussion and misunderstanding regarding the goal and nature of the TRM process. It was not clear for some of the participants what the intention of the process was and questions were raised whether the term roadmapping was defined properly. Subsequently, a discussion emerged regarding the strategic setting and premises for the TRM process. Both discussions took longer than expected; therefore several adaptations had to be made during the workshop itself. The brainstorming of the market drivers was done collectively, while the plan was to do this individually. This saved a significant amount of time, but the amount of identified drivers suffered because of this. The following block had the purpose of finding challenges that were related to these different drivers. The use of a brainwriting method worked well and let to the identification of several issues related to the drivers. A discussion of the challenges had to be skipped, but these challenges were proven helpful during next workshops. The last block contained the prioritization of the respective drivers for TC as a whole and the relevance of each driver for the different product families. Putting the long initial discussion aside this workshop went smoothly in general and led to relevant drivers.

The validation of the content of workshop is presented next. During the evaluation interview which was conducted the day after the workshop it became clear that the identified drivers reflected the ideas of the leader of the strategic planning department. He explained: “From a firm point of view

the first three drivers are the most important ones. The last driver came up during the workshop, so I have some doubts about this driver because this driver is not seen by the managing directors or by the department leaders in that sense". All interviewees agreed that the discussion regarding the strategic setting and premises should be avoided during the workshop. Therefore it was proposed to hold "a briefing session with everybody as this would be very helpful to make sure that we can really start with the content of the workshop how they are planned. And that we don't have to explain again why are we doing this at all" by the external consultant. During the workshop there was no time left to discuss possible business drivers. In order to look for gaps it was discussed to add the business driver "innovation". The leader of the strategic planning department agreed as he responded: "from a corporate point of view you can derive drivers from the strategic targets, mission and vision, this is fine". Based on the mission of TC it was agreed to include the business driver "innovation" to look for gaps. Four prioritized market drivers and one business driver served as validated input for the second workshop.

4.2.2.2 Product-service workshop

The goal of the product-service workshop was to identify a set of prioritized product-service features which satisfy the identified drivers of the first workshop. In total seven participants were present from the product management and toll data departments. Table 8 shows the agenda of the product-service workshop.

Block	Time	Method
Introduction	5 min	
Present previous results	5 min	
Explain process	10 min	
Identify features from perspective customer	60 min	5x5 min individual brainstorming on cards and grouping during a 35 minutes lasting discussion
Identify features from perspective user	60 min	5x5 min individual brainstorming on cards and grouping during a 35 minutes lasting discussion
Prioritization	30 min	Individual
Closing	10 min	

Table 8: Agenda of the product-service workshop

The agenda of the workshop was largely the same again as the standard T-Plan. However, the implementation of the product-service layer implicated that the focus during the workshop was on the core offerings of the company instead of specifically referring to products or services. Another difference with the normal approach is that a distinction was made between the user and the customer during the identification of features. The reason for this is that the existence of the contract indicates that there is a separation between these actors. The customer is in this case the government, while the truckers and the logistical companies use the services of TC. In order to incorporate both views two different blocks were implemented where the participants were given the order to think from a user perspective in the first block, while thinking from a customer perspective during the second. The aim of this was to obtain more diverse features. Lastly, the MV product manager presented the product strategy because this largely been fixed within the company.

The key successes and failures are presented in this section. Several new participants were present during this workshop. Therefore they had to be informed about the TRM process and the results of previous workshop. This took longer than expected again. Finding features from the perspective of the user went well. However, within the available timeframe it was not feasible to do the same process again due to time limitations. Instead of discussing the features collectively this time, the participants pinned them to the whiteboard themselves. As there was a lot of overlap between the ideas of both perspectives this went well. In total 160 ideas were pinned to the wall and during the discussion, this lead to the identification of 60 groups of features. As there was not enough time to go through all the ideas again and judge whether they are real features or more conditions that have to be met, these 60 groups of features were prioritized. Every participant was handed over a sheet of paper on which the features were written down. The participants prioritized the features for the different drivers.

During the validation process the external consultant pointed out that “we were all surprised by the amount of features they found and discovered. That was a very positive surprise, but let us to the problem that we in fact should not have done the prioritization right after the grouping of the features”. The prioritization took 35 minutes as the participants had to rank 60 groups of features for five drivers. Although it was tough for the participants the MV product manager pointed out that “it was very useful for me. [...] The different points of view were very helpful”. The head of the product management department added that the prioritization “was the objective. [...] So we don’t have the subjective feeling anymore. For that, it was very important”. During the validation it furthermore became apparent that not all features were on the same level of detail. Several features had to be grouped together, while others were split up into multiple features. Additionally, some ideas that had been identified as features were not real features but conditions that have to be met in order for a feature to be implemented. Even though this is not ideal, the quality of the identified features was high. The MV product-manager was asked which features she wanted to implement. She responded with: “I want to implement all of them!”.

4.2.2.3 Technology workshop

The aim of the technology workshop was to link the identified features to technologies that enable them. Eight participants from the product management and toll data departments were present. As explained earlier adjustments were made to the list of features. Due to time limitations not all features could be explored. For the eight highest prioritized features technologies were sought for. The agenda of this workshop is shown in table 9.

Block	Time	Method
Introduction	10 min	
Benchmarking	30 min	Collective discussion
Develop SWOT analyses for every feature	60 min	Group work
Presenting SWOT’s	40 min	
Prioritization of technological gaps	30 min	Individual
Closing	10 min	

Table 9: Agenda of the technology workshop

A benchmarking block was added to the agenda of this workshop. The rationale behind this was to identify which competitors already offered the identified feature. In addition, the plan was to identify the technologies that this competitor uses. This had the potential of finding technological gaps. Technological solutions were sought for with the use of a SWOT analysis. Under the heading of *opportunities,* technologies that could develop or enable a certain feature had to be written down. The *strengths*, *weaknesses* and *threats* were incorporated in order to have a clear overview of the positive and negative sides of a technology. This had the potential of enhancing the decision making regarding the priority of a technology.

This section displays the successes and failures of the workshop. Two new participants joined the workshop. For them the aim of the TRM process had to be explained again. Additionally the outcome of the previous workshop was presented. During the elaboration of the benchmarking it became apparent that the features were still not on the same abstraction level. It was decided to move three features to one other feature. Of the initial eight features, five were left. The benchmarking itself did not led to great results either. The participants did not have enough knowledge about which technologies competitors exactly used. Therefore the results were rather shallow. The identification of technologies was very difficult for the participants and therefore the outcome was limited and superficial. The original plan contained the creation of SWOT analyses in two different groups. Those analyses would be presented by the respective group. However, because the features had been grouped together and the identification was difficult it was decided to do this collectively with the entire group of participants. An impact ranking was also hard as the participants could not assign different priorities to the identified technological gaps. A gap analysis had to be skipped because there was not enough time left to conduct this analysis.

During the validation step special attention was paid to the lack of technologies. The interviewees indicated several reasons for the lack of technologies on the roadmap. First, according to multiple interviewees the nature of the product itself caused a limited amount of technologies. The MV product manager explained: “it was no surprise that we did not have so many ideas of new technologies. The subject is toll collection, and MV is a manual process and you can do it online or via smartphone or telephone. But there are not that many other technologies”. Second, the methodology was questioned by two interviewees. The external consultant explained: “One factor for sure is more methodological. I don’t think they really got the idea what kind of technologies we are thinking of or asking for. [...] So there was no clear understanding of what we talked about. Not all participants knew what they should say or write down”. Third, the firm is not pro-active but reacts upon the requirements of its customer. The MV product manager advocated that: “We always react from the requirements of our customer. But there is no development process in our own minds”. Fourth, three interviewees pointed out that the features can be implemented with existing technologies. The product manager said that “this was related to the product itself. It is a well known product and concerning new technologies, you have a lot of standard technologies to implement the features. There is no need for really new technologies”. However, the head of the product management department strongly disagreed. He said: “That is from my point of view not true. Because mobility, that was one of the major features we have identified, is currently not implemented in our architecture. It is new, it is not new to the world, but it is new for this company. This is an issue, this is a technology that we have to implement and which we have to put on the roadmap as technology topic as well”. Fifth, the MV product manager carefully put the lack of expertise forth: “maybe we were not with the right participants”. The head of the product

management department disagreed again and put forward that the toll data department was present with three persons and that “the toll data department is the technology department in this firm”. However, the external consultant explained that “the Toll data department does the modeling of toll maps, which are the basis for AV and MV, and handles many data derived from AV and MV users. In addition to that, there are some other departments with a more operational focus”.

As so little technologies had been identified during the third workshop the plan had to be changed. The initial idea of the fourth workshop was to look into current systems, architecture and projects of TC. However, with the limited amount of technologies this would have had very limited value. In addition, the essence of the systems workshop was questioned. During the preparation of the workshop the TRM team found that it is very difficult to determine how the current systems and architecture change based upon features of which the exact specifications are not known. In addition, the added value was questioned as the systems that are in place within TC are dynamic. Therefore they change over time. Making an assessment of how a feature that is implemented in five years affects the current systems has very limited value as it is likely that the systems have changed by then. Instead, a gap analysis which had not been conducted during the third workshop was implemented. It was changed into a “technology-push” workshop.

4.2.2.4 Technology-push workshop

As explained in the previous section the systems workshop was replaced with a technology-push workshop. The main point of this workshop was to look with a “technology-push” lens towards the technologies and features. This is in essence a gap analysis for both features and technologies, as this was not done during the previous workshop. This means that the features and technologies did not necessarily had to be related to a market or business driver, but that also other ideas which could be relevant for TC were identified. Seven employees of the product-management, toll data and strategy departments attended this workshop. Table 10 gives an overview of the agenda of that day.

Block	Time	Method
Introduction	15 min	
Identification of potential important technologies	60 min	10-15 min individual brainstorming on cards then discussion
Identification of potential important features	60 min	10-15 min individual brainstorming on cards then discussion
Prioritization	30 min	All participants get a standard set of points which they can distribute
Closing	10 min	

Table 10: Agenda of the technology-push workshop

A technology-push workshop was not found within the literature. Therefore an own agenda was developed for this. As the brainstorming method had proven to be effective during earlier workshops this was used as the creativity method of identifying technologies and features. The differentiation between the user and customer was made again.

A short overview of the successes and failures is presented in this section. The workshop started with a short summary of the outcomes until then. The following block aimed at coming up with

technologies that could be relevant for TC until 2023. The original idea was to do this first individually, but this was too hard for the participants. Therefore it was chosen to do this collectively. Through a discussion the quality of the ideas was good and a dozen new ideas were identified. These were not only technological gaps, but also some additional features were identified. The prioritization went especially well during this workshop. The ideas were pinned on a blackboard and the participants were handed over ten small stickers, where each sticker represented one prioritization point. All participants were asked to come forward and to put their stickers on the features. This was a very fast and effective approach to prioritize when there is no distinction between market segments.

The validation showed that the same reasons as pointed out in the technology section limited the identification of new technologies. Despite the limited amount of technologies the product manager explained that afterwards he was "quite satisfied with the result". For the external consultant the technologies were not the major focus of this process: "I see that as secondary information for the whole roadmap. That is at one point because the main technologies that we need already exist and we did not come up with any possible future technologies that could help us in any way". The technology workshop did have value for the MV product manager: "Yes, it is very valuable and you have to do these workshops from my point of view. [...]It was interesting to see the outside view and to see which features can be in the market in the future and then to match it with the results we reached in third workshop. That was very interesting". Also the head of the product management department saw the value of the technology workshops. He explained: "To bring a service to a success, it is necessary that you do not only follow the market requirements, but you have to follow the technology drivers as well. It is a question of efficiency, of market acceptance, of user acceptance. For that we for sure have to anticipate which technological trends we have to take into account for the next years. [...] There are a lot of layers that we have to discuss and that is one of the purposes of why we have five workshop rounds. To discuss every of these layers separately with a specific focus point to see what is really important and interesting for our product".

4.2.2.5 Roadmapping workshop

The aim of the final workshop was to bring the gathered information of the previous workshops together and chart the layers of the roadmap. In total eight participants of the product management, toll data and strategy department were present. Table 11 gives an overview of the agenda of the last workshop.

Block	Time	Method
Introduction	5 min	
Summary of results	20 min	
Plot drivers	20 min	Collective discussion
Plot and link features	45 min	Collective discussion
Plot and link technologies	45 min	Collective discussion
Determine potential issues	20 min	Collective discussion
Discuss whether current implemented features should be kept	15 min	Collective discussion
Closing	10 min	

Table 11: Agenda of the roadmapping workshop

Comparing this agenda to the agenda of the standard T-Plan shows that they are alike. One addition was made to the agenda of the standard approach. As the roadmap is focused on *change the business* the features that are currently available within TC have not been plotted on the roadmap. Instead, the idea was to pin them on another blackboard and to create a discussion whether the features were desired in the future.

Key successes and failure are given in this section. The workshop went according to the initial plan. During the mapping of the features, it was decided to make a distinction between optional and obligatory features on the roadmap. This was done because some features are nice to have, but are not essential for the MV product-family. Seven features which were not feasible according to the requirements of the contract were pinned in an "idea back-log". A total of eighteen features have been plotted on the roadmap. An additional thirty features were pinned on a separate board, and it was discussed whether they should be kept, changed, or whether they are not needed anymore. This led to good discussions, and some features were only desirable under certain conditions. These conditions were also attached to the current features. Additionally, issues regarding features were plotted on the roadmap. During the plotting of the features there was a clear negotiation between different departments whether pinning a feature on the roadmap or not. Illustrative for this was whether a feature should be implemented. For the product management department this was a very nice feature for the products, but the toll data department argued that "this makes the architecture only more complex, and what is the benefit of it?". The result of this workshop was good. The validation of the roadmapping workshop is incorporated in the following paragraph.

4.3 Outcome of the TRM process

In order to judge the success of the project the interviewees were asked to what extent they think the main objective of the TRM process had been reached. The product manager was positive: "I think that the outcome is valuable. And the goal to have a technology roadmap is realised. Maybe one weakness is that we do not have a deep technology forecast. This is something we should prepare before the third and fourth workshop starts. That we have some technology research and use that as an input for the third and fourth workshop. Because to just ask the participants what the new and upcoming technologies are in ten years is something they could not answer". The external consultant argued: "The problem we had in the beginning of the discussion is that the three of us had a different understanding of the technology aspect of the roadmap. That is one point that should be discussed in the beginning. What do we understand under the roadmap, and what do we want to get out of it. For me, the technology was never such an important part of the whole roadmap. The market view and as a result the derived features. I see it more as a feature roadmap, than a technology roadmap. From that point of view the outcome was good. It was kind of what I expected and hoped for. We do have a good view on features now that we could realise in the next years. And they are related to the most important market events. We now have an idea how to react to market events. From that point of view it is good!". The MV product manager was also positive: "I think it is fulfilled. We have a good idea of all the product features that are useful for me and with a time planning and the relation to the market drivers". The product management department leader agreed: "I think for an initial result it is fine. It is not finalised from my point of view, I think we need a few iterations. [...] It was a very compact approach to get results in two weeks. We have an initial idea of the content and timeline of our product. […] For a test-run it was excellent!".

5 Discussion

This study has attempted to develop a suitable TRM process for and within a service-oriented firm. In order to answer to what extent this has been achieved an assessment is made whether the architecture has been customized based on the correct variables and whether the architecture was customized properly. Then, the customization of the process design is discussed. The extent to which the TRM process was a success follows. An overall evaluation of the suitability of the TRM process for TC is made lastly.

5.1 Customization of the TRM architecture

This section aims at making an assessment whether the customization process of the architecture has been based upon the correct variables and whether the architecture has been customized properly. Therefore this answers sub-questions 4 and 5. A detailed elaboration on these findings of these variables can be found in paragraph 4.1.

5.1.1 Purpose

The purpose of the TRM process influenced the choice of a generic starting TRM process. According to Phaal et al. (2004b) the customization of the architecture is largely dependent upon nature of the issue that triggered the interest in roadmapping. Based on the goal of the organization the product-technology framework was chosen as the basic framework. This framework combines the marketplace, the core offerings of the company and the technological luggage to develop the core offerings. Another generic TRM framework that would have been possible as a starting point for this project is the business reconfiguration framework that Phaal et al. (2004b) describe. This framework integrates the same layers but it is more focused at bridging the gap of the current position of a firm and its future vision which indicates that it serves a different purpose. However, in this case the company did not have a future vision that diverted much from the current strategic position. The choice of the product-technology planning framework has been a proper choice because the different layers of this generic framework all had added value in reaching the goal of the TRM process. The main advantage of this generic framework was that explicit linkages between the market, services and technologies were made. The choice for this framework shows that it is essential to develop a clear view of the purpose prior to the initiation of the workshops as these workshops help to achieve the main goal. If the purpose is not entirely clear at that point, workshops could be organized which do not help to reach the goal of the TRM process. Thereby resources are ineffectively used. This supports the findings of Phaal et al. (2004b) and Gerdsri et al. (2010) who argue that it is important to develop awareness of why TRM is necessary and to develop the objective of the process in the planning phase.

5.1.2 Product-service system integration

The richness of features within the product-service layer indicates that the implementation of the product-service system concept as a separate layer was successful. Another option was to implement both a product and service layer. However, in this case the concepts of products and services were used interchangeably within the company and therefore the combined view fitted better with the mindset of the company. The main benefit of the combined layer is that the participants were able to think of end-user noticeable features, whether these features were product or service specific features made no difference. In this case, making a distinction between product and service features as Geum et al. (2011a) did would only have increased the complexity without much added benefit because the company uses the concepts interchangeably. These findings confirm that the boundaries

between products and services are fading as Drejer (2004) described and that the use of an integrated PSS layer can be helpful for a firm that does not make an explicit distinction between products and services. Customizing the architecture based on this variable has been a good decision.

5.1.3 New service development

The third variable upon which the architecture was customized was the high connectivity between the back- and front-end of a service. This resulted into the systems layer which had the aim of showing how the current architecture of services will be affected by new technologies. Such a layer was not found yet within the academic literature. After the evaluation of the technology workshop it became apparent that the implementation of such a layer would not have had much added value for a technology roadmap for multiple reasons. First, it is very difficult to establish the influence of a feature or technology that is not yet present within the organization and might only be implemented within five years. The exact specifications of a technology are not known and therefore this step would have relied much on speculation. Second, the systems and architecture of a service are dynamic. This means that these change over time and that an assessment of how a feature influences the current architecture makes no sense as the architecture might look different at the time when the feature is implemented. Therefore it can be stated that the addition of such a layer has limited added value for a technology roadmap.

5.1.4 Contracting out

The fourth relevant variable is the contract that a service firm has with its client. The findings of the study demonstrated that the company has trouble with thinking beyond the term of the current contract without letting go of the current features of the contract. These results are in line with the findings of Autor & Houseman (2005) and Lee et al. (2009) who argue that a defined contract tells a firm to provide a certain service and the provider of the service just does this. In relation to the architecture of the TRM process the sub-layers of the product-service workshop were customized. The contract implies that the user is not the same actor as the customer. Therefore making a differentiation between these two different points of view to come up with features has proven to be effective. Such a differentiation of points of view was not found within the academic literature, but it is useful for firms who are in the same position. The firm was usually only looking at the needs of their customer, however by being pro-active and taking the perspective of the user into account new features were identified. Hence, customizing the architecture based on this variable has been a good choice.

5.1.5 Conclusion

The responses of the evaluation interview show that the interviewees did not think that any other variables have had an influence on the TRM architecture. Also, in retrospect no other variables could be appointed which should have been taken into account during the customization process. Three of the four variables that have influenced the customization were correctly chosen. Based on the fact that no other variables have been identified that should have been a base for customization and that overall the variables that were chosen have affected the process can be said that the architectural customization was executed properly.

5.2 Customization of the process design

The aim of this paragraph is to assess to what extent the process design has been designed properly, thereby an answer is found on sub-question 6. As the available guidelines do not specify how to

reach the objectives and no practical experience with TRM was present in the team these methods have been created by the TRM team. Key successes and failures of the process design that have affected the quality of the TRM process are discussed. The discussion has been based upon the findings which are presented in paragraph 4.2.

5.2.1 Planning phase

The findings show that within the preparation phase a clear separation was made between the different roles of people in the TRM team. The establishment of role separation within the TRM team created clarity of tasks and responsibilities. In addition, the TRM team had been composed in such a fashion that different types of expertise were present as Gerdsri et al. (2010) recommended. The researcher had the theoretical knowledge, the product manager had experience with mediating workshops and the external consultant had in-depth knowledge of the services and processes that were in place. A downside in this respect was that nobody had practical experience with TRM. Phaal et al. (2004a) state that ideally someone proficient in roadmapping manages the process and facilitates the workshop. In the same light Gerdsri et al. (2010) show that an external TRM team helped the organization in their guideline. Therefore the process could have been better if someone with this experience had complemented the team. In order to compromise for this lack of practical experience the TRM team met seventeen times prior to the workshops to familiarize themselves with the process and to prepare the workshops. In retrospect these meetings were absolutely necessary. The diversity of the TRM team and the extensive preparation enabled a proper facilitation of the workshops because each TRM team member had his own expertise and the workshops had been planned and prepared in detail.

5.2.2 Development phase

This section aims at discussing the key successes and failures of every single workshop. This relates to the customization of the process design, which is the third factor upon which the suitability of the TRM process is based. Lastly, a conclusion of the suitability of the process design is given.

5.2.2.1 Market workshop

The findings from the market workshop show that valuable time was lost during this workshop due to an extensive discussion regarding the premises and setting of the TRM process. As a result less time than planned was assigned to the identification of drivers. This outcome could have been improved when a proper kick-off meeting was held where these matters are discussed. Although Phaal et al. (2004a) and Gerdsri et al. (2010) explain that participants need to be prepared, they do not clearly state how this should be done. Gerdsri et al. (2010) do state that a kick-off meeting was organized in their guideline example, however they do not give an explicit recommendation that this is a necessity. These findings show that informing participants through written documents and informal talk was not effective enough and that a proper meeting with as many participants as possible needs to be held to discuss the TRM process.

Aside from the lost time due to emerging discussions the outcome of the workshop was good. The validation interview confirmed that the identified drivers were of high quality. The nominal group technique and brainwriting were useful creative methods in this respect as Thompson (2003) explained. A standard SWOT analysis was not used as Phaal et al. (2004a) propose. This was partly caused because Phaal et al. (2004a) do not clearly describe how the SWOT analysis should be carried out. The added value of finding opportunities and threats was not identified by the TRM team.

However, the findings do indicate that replacing the SWOT analysis with the nominal group technique and the brainwriting method was successful.

5.2.2.2 Product-service workshop

From the findings can be drawn that new participants caused time loss because the goal had to be explained. This supports Phaal et al. (2004a) their statement that it is better to keep a core group of participants continuously involved with all workshops. As the workshops build upon previous ones it is evident that for the understanding of the content of the roadmap it is better to have a core group of experts in all workshops. How big this core group depends upon the resources the company is willing to invest, but the effectiveness of the workshops will be improved with continuous participation. A consequence of the long discussion was that there was too little time left to complete the entire agenda of the workshop.

A very specific aspect of the process that demands the attention is the prioritization method that was used. The findings show that the usefulness of the prioritization was limited because there was an overload of identified features and these were not all on the same level of abstraction. This indicates that the grouping of the features within the workshop was not effective enough. After the workshop some features have been grouped together or separated after the prioritization process. If more than twenty features are identified it is better to do the prioritization after the workshop and send the participants the list of features. In addition, the moderator of the workshop should make sure that the features are on the same level of abstraction. This pitfall is not explicitly mentioned by TRM scholars, but it is certainly important to consider because it affects both the market and technology foresight integration. Babbie does explain that with focus groups the moderator falls or stands with the skills of the moderator.

From a process design perspective the differentiation between features from users and the customer was a key success. By clearly differentiating between these actors, participants take a different mindset and come up with new features of which they had not thought of before. In this case, the participants were used to be thinking from the perspective of the customer because the company gets paid from this customer. However, it is also in the interest of the customer that users get better features. The differentiation between the different actors was not found in the academic literature, but it certainly added value.

5.2.2.3 Technology workshop

The findings of the technology workshop indicate that this was one of the hardest workshops of the series which resulted in a limited amount of technologies on the roadmap. A major cause of the lack of technologies was that the participants did not exactly understand what kind of technologies should be included on the roadmap. Whether these should have been new to company, new to the industry or new to the world was not clear. An option to improve this is to discuss the setting of the technologies in advance and give an example of a possible technology. Thereby guidance is provided to the participants. Phaal et al. (2000) state that the biggest barrier to success is that the required data, information or knowledge was not available. In this case it was not necessarily the fact that it was not available, but the knowledge was not accessed entirely due to a lack of understanding of the concept of technology. This can be seen as a lack of facilitation or training as Phaal et al. (2000) indicate.

Focusing on the applied methods, using a SWOT analysis method for finding technologies was not effective. Each feature was displayed on a sheet of paper with the four headers of a SWOT analysis. Under the header of *opportunities* possible technologies were listed. The strengths, weaknesses and threats of a feature were also listed, but in the end not much was done with this information. The time spend on finding these other headers would have been better spend directly on discussing more or other relevant technologies. Using a brainwriting method as was used for the identification of features can be a valuable method because participants see which technologies are already identified and can think of other or related technologies. This would likely have increased the amount of identified technologies.

On a more organizational level, the time in between the workshops limited the quality of the roadmap. During this run-through the TRM team had one day in between every workshop to evaluate the last and prepare the following workshop. Especially in between the product-service and the technology workshop this timeframe was too short to properly analyze the features and prepare a list of technologies. A few more days in between the workshops would likely increase the quality of the roadmap. Research undertaken on technology roadmapping has indicated that a lack of effective facilitation or training limits the results of the TRM process (Phaal et al., 2000). These findings support that in order to effectively facilitate the workshop the TRM team needs a few days in between the workshops to analyze and prepare the workshops.

5.2.2.4 Technology-push workshop

As the findings indicate using a technology-push workshop works well to find gaps within the technology layer of the roadmap. Because participants are not directly thinking from features, but are taking a more general perspective new technologies and features were identified. Phaal et al. (2004a) implement this in their normal technology workshop as a gap analysis. If there is enough time left during this regular technology workshop it is evident to execute this in that workshop. However, during this cycle there was not enough time left to conduct the gap analysis and in order to find more relevant technologies it was a good opportunity to make this the focal point as a technology-push workshop.

5.2.2.5 Roadmapping workshop

The findings from the roadmapping workshop indicate that planned activities were carried out properly and led to an acceptable result. In comparison with the generic TRM process a few deviations were made. First, during the mapping of the features on the roadmap an additional prioritization was made. It was decided that a differentiation between optional and obligatory features on the roadmap would help the product manager with the identification of the most important features. This is not part of a generic roadmap, but it gives added value in the sense that it gives a clear overview on the roadmap of the highest prioritized features. Second, as the company had recently finished a project which had the focus of identifying incremental projects this roadmap had the focus of identifying new features which were not in place yet. Therefore only new features were pinned on the roadmap and current features were kept in an idea backlog. This is also not a standard procedure within a TRM process, but it helped to create clearness on the roadmap itself.

5.2.2.6 Conclusion

From the above elaboration the conclusion can be drawn that the overall TRM process design was proper. Of course there are several aspects of TRM design that could have been better, but one

should take into account that the process was new to firm. In addition, nobody within the organization had previous practical experience with TRM. Lastly, the availability of methods that explain in detail how the workshops should be handled was lacking. As with every new process several iterations can improve the structural design of the TRM process, but for a first run-through the process design enabled the development of a roadmap within a very short timeframe.

5.3 Outcome of the TRM process

This section relates to sub-question 7 and aims at assessing to what extent the TRM process was successful. The primary goal of this research was to design a TRM process that is suitable for a service oriented firm. According to Gerdsri et al. (2010) the rate of success of a TRM process can be determined based on the extent to which the objectives of the process have been met. By decomposing the main objective it becomes apparent that on the one hand market foresight and on the other hand technology foresight had to be integrated and aligned with the new service development process of the firm.

Market foresight is displayed within the market layer of the TRM process. Within a timeframe of ten years the four most important market drivers have been plotted on the roadmap. Subsequently, a total of twenty features that have the potential to satisfy these market drivers have been connected to them. The link between these two different layers is the integration and alignment of market foresight with the new service development process of the firm. As the findings of the outcome section indicate a clear view has been developed how the firm should react upon future developments within the market. Based on the number of identified market drivers, their connections with features and the positive reaction of the firm it can be stated that market foresight has been integrated successfully with the new service development process.

The purpose of the technology layer was to display potential technologies that enable a specific feature. In addition, the technology-push workshop had the aim to identify technologies that could be relevant for the company in the future without the necessity of being connected to a feature. In total three technologies have been plotted on the roadmap, with one connection to a feature. Multiple interviewees indicated that there is a lack of technological foresight present within the roadmap. Taking the number of technologies, their connections with features and the negative reaction of the firm into account it is evident that technological foresight on the roadmap is lacking.

In this light it is important to consider why technological foresight is lacking. A differentiation is made between internal and external factors. Factors that go beyond the power of the TRM team are defined as external factors, while internal factors are those that the team did have a direct influence on. First, the applied methodology created confusion among the participants as discussed in paragraph 5.2.2.3. This is an internal factor that was influenced by the TRM team. Second, TC is a highly specialized company which is reflected in their organizational structures. There is not one R&D department, but several specialized technological departments. As there was one technological department present during the technology workshops not every technical point of view of the service was taken into account. So there was a lack of technological knowledge. Phaal et al. (2000) demonstrated that having the right people involved is crucial for TRM success. Although the TRM team knew that this would limit the findings, it should be taken into account that for this first run-through a limited amount of resources were available and not all departments could be invited. This is clearly an external factor. Third, the nature of the service itself was a limiting factor. The

application of the roadmap was on the manual toll collection service-family. The goal of this service is to give users the opportunity to buy a ticket from a vending machine or to log-on to the system via internet to pay toll. As the findings indicate offering this specific service in the future does not necessarily require many new technologies as opportunities to deliver this service in other manners are rather limited. No scholars have articulated the nature of the service as a barrier to the success of TRM. However, it is important to consider in relation with TRM as it affected technology foresight. The nature of the service is not something that the TRM team has an influence on; therefore this is seen as an external factor that influenced the process.

Taking the above into account the objective has been reached to a certain extent. It is evident that market foresight has been integrated successfully, while technological foresight is lacking. However, while assessing the success of the objective one should realize that external factors, over which the TRM team has no control, have influenced the success of the outcome in a negative manner. In addition, the findings of the success of the TRM process show that the firm is very satisfied with the implemented process. Many potential new features have been identified to satisfy the market drivers. All in all, the outcome of the TRM process is not perfect, but still of a high level.

5.4 Evaluation of the suitability

The discussion has been structured in such a fashion so the suitability can be assessed based on four pillars. First, the most relevant variables for a service-oriented firm have been identified for the customization of the architecture. The findings indicate that the most important variables for a service-oriented firm have been identified. Second, the customization of the architecture has been done properly as each layer has had added value in achieving the main goal. Third, the activities of each single workshop have led to appropriate results. This is important to consider because the output of one workshop serves as input for the following. This shows that the process design was properly developed. Fourth, the rate of success of the process is twofold: market foresight has been integrated with the new service development process while technological foresight is lacking. However, it has been explained that the lack of technological is partly caused by external factors that go beyond the influence of this TRM process. As the findings indicate, the outcome of the process is useful for a service oriented company and the TRM process gives them a structured way of developing linkages between market developments, their core offerings and technologies that enable these offerings.

6 Conclusion

This chapter aims at presenting the conclusions of this study first. Thereafter the limitations are presented. Lastly, the extent to which the findings of this study can be generalized is discussed.

6.1 Conclusions

The research objective of the research was based upon an identified gap in the academic and practical world. Therefore an action research design was chosen to address both issues. A research framework and seven sub-questions were developed with the aim of providing support in answering the main research question.

- What constitutes a suitable technology roadmapping process for a service oriented firm?

Four pillars have been identified that encompass the suitability of the technology roadmapping process. The first aspect encompasses finding the correct variables upon which the decision is made to customize the architecture of the roadmap. Subsequently, the second aspect relates to how the TRM architecture should be customized based on these variables. A framework was designed for this purpose which led to the identification of four main variables that affected the customization of the roadmap architecture. First, the purpose of the roadmap led to the choice of using the product-technology roadmap as a starting framework. Second, as terms for products and services were used interchangeably the standard product layer was replaced with a product-service layer, whereby the concept of PSS was incorporated into the roadmap. Third, it was found that the front- and back-end of a service are highly related. Therefore a layer which had the purpose of linking technologies with the current systems and architecture of the firm was added to initial plan. Fourth, a contract with the government implies a differentiation between the user and the customer on the roadmap. Three of the four variables have been correctly chosen and the technology roadmapping process has been customized accordingly. No other variables could be identified in retrospect. Therefore the conclusion is drawn that the key variables upon which a service-oriented firm should customize their architecture have been identified. In addition, the architecture has been customized in such a fashion that the main goal of the process has been achieved. It is concluded that the architecture has been customized properly based on the identified variables.

The third aspect of the process involved the customization of the process design. There were no large problems with the outcomes of the market, product-service and roadmapping workshops. However, during the technology workshop a problem did rise as a limited amount of technologies had been identified. This was caused by three main factors, namely the organizational structure of the firm, the nature of the service itself and a lack of clearness of what was expected from the participants. Based on the scarcity of identified technologies combined with a doubt regarding the added value of the workshop it was decided to delete this layer from the TRM architecture. Instead a technology-push workshop was organized which was in essence a gap analysis because this was not done in the previous workshop. Although the volume of the identified technologies was limited, only one internal factor was a cause of this namely the used methods. To conclude, the activities of each single workshop have led to appropriate results. This is important to consider because the output of one workshop serves as input for the following. This shows that the process design was properly developed.

The last step for assessing the suitability of the roadmap encompasses the success of the outcome. As the roadmap gives the company a good view of how they should adapt their services and technologies in order to satisfy market drivers within the coming ten years the success of the roadmap has been proven. In addition, the findings of the success of the TRM process show that the firm is very satisfied with the implemented process. All in all, the outcome of the TRM process is not perfect, but still of a high level.

Based on the evaluation of the identified variables, the customized architecture, the customized process design and the overall outcome it can be stated that for a first test-run the process has been successful. This supports the design of a suitable TRM process for a service-oriented firm. Compared to generic TRM frameworks the findings show that the TRM process within this service firm deviates in multiple ways. First, an integrated layer of products and services fits within a service firm because of the fading boundaries between products and services. Second, participants have to be pushed to go beyond the term of a long-lasting contract. Third, making a differentiation between the user and customer helps with identifying features in the product-service workshop. Fourth, technologies were relatively difficult to identify on the roadmap mainly because of the used methodology, the organizational structures and the nature of the service.

6.2 Limitations

Social scientists in general tend to have limitations and problems. In action research some of these dilemmas are stronger because action researchers seek to address both practical and theoretical issues. The adoption of this approach leads to a number of main limitations and pitfalls (Baskerville & Wood-Harper, 1996). First, the researcher is actively involved with solving a practical problem. In this case the researcher has been part of a TRM team which implemented a TRM process. According to Avison & Wood-Harper (1991) this leads to impartiality and biases of the researcher. Second, action researchers tend to have a lack of scientific rigor and discipline (Baskerville & Wood-Harper, 1996). This is often reflected in a lack of validity of the data. Third, action research is sometimes mistaken for consulting (Baskerville & Wood-Harper, 1996). Fourth, the generalization of the findings is difficult because of the context-dependent setting of a study (McKay & Marshall, 1999).

In order to address these limitations and pitfalls several measures have been taken. First of all, to enhance the impartiality and to limit the bias of the researcher the roles within the TRM team have been explicitly determined. The researcher had the role of methodological expert while the other team members had expertise in organizational knowledge and services. Besides limiting potential biases and increasing the impartiality of the researcher differentiating roles in the TRM team increases the scientific rigor and discipline of the study (Baskerville & Wood-Harper, 1996). Second, the data collection approach has been described in detail. This distinguishes the empirical character of action research from consulting (Iversen et al., 2004). In addition, multiple sources of data have been used to reduce biases and to increase scientific rigor. Third, the establishment of the usefulness of the results supports the impartiality of a researcher and establishes a baseline of the generalization of the results (Baskerville & Wood-Harper, 1996). To address this point an assessment has been made regarding the suitability of the TRM process for a service-oriented firm. In addition, special attention has been paid to the usefulness of the TRM process during the evaluation interviews. Fourth, the results should be related to existing frameworks. This is addressed within the discussion section, where the findings of the thesis are discussed in combination with existing scientific research. Fifth, the conditions for transferability are discussed.

Despite the implementation of multiple measures to address the limitations no study is completely perfect. First of all, answering the research question is a subjective matter. Suitability relates to whether the process fits with the context and characteristics of the firm. However, this is difficult to objectively measure. Therefore, multiple indicators have been chosen to assess the suitability. But even the assessment of these indicators is subjective because one relies on the opinions of participants and the analysis of the researcher. Second, related to the previous point is that the quality of the roadmap heavily relies on the expert knowledge of the participants. Having the right participants within the workshops is crucial for the success of the roadmap. This also indirectly influences the success of the TRM process because in this case the success of the TRM process is partly judged by the success of the roadmap itself. Third, the generalization of the outcome is limited because only one case has been studied.

6.3 Generalizibility

An important issue is to assess to what extent the suitability of the TRM process can generalized to other settings. In order to develop this assessment five conditions that Iversen et al. (2004) mention for action research are presented in table 12 and subsequently discussed.

(1) What is the area of application outside which the approach is likely not to be useful?
(2) Under which conditions (e.g. time and resources) is the approach applicable?
(3) Is it possible to make the approach understandable to others?
(4) What are the skills and capabilities that facilitators and other actors must possess?
(5) To what extent is the approach kept general to increase transferability, as opposed to being made specific to increase usefulness in the organization?

Table 12: Conditions for assessing the success of action research

The first point they raise is where the approach is likely not to be useful. It can be claimed that it will likely not be useful for roadmaps on industry and national levels because the approach is focused specifically on a firm level to identify product and service features. In addition, the presented framework will probably also not work for firms that have an entirely different purpose and characteristics. This TRM process is focused on developing linkages between the market, services and technologies. Firms with other purposes are likely better off with a different structure. Secondly, the conditions under which the approach is applicable should be stated. The entire process took approximately five months. The TRM team consisted out of three people of whom two were employees of the firm. However, these two were not full-time involved with the process. During the preparation seventeen official meetings have been held and subsequently five workshops have been organized. During these workshops on average seven participants plus the TRM team were present for three hours. If an inexperienced firm wants to adopt the process it is recommendable to organize these meetings in the preparation to create a common understanding and customize the process. Third, it is certainly possible to make the approach understandable to others. The overall target and process is relatively easy to explain because much literature is available and the high-level goal can be visualized with an example. However, one should take into account that from the academic literature not all exact methods of the workshops are explicitly mentioned. Fourth, the skills of the moderator during the workshops are very important. His or her task is to lead the workshops to a good outcome. Therefore good leadership skills combined with a proper understanding of the TRM process is necessary. Fifth, the approach is kept general in the sense that a TRM framework has been based upon two generic frameworks of Phaal et al. (2004a) and Gerdsri et al. (2010). However, the TRM process has specifically been designed for a service-oriented firm which has a contract with a

client. Several modifications have been made to customize the process to these characteristics. Therefore the presented framework is most likely to be successful at a firm with a relatively similar context and characteristics. On the one hand it cannot be said that it will definitely not work for other firms because the main structure is relatively generic, on the other hand every TRM process should be customized to the context and characteristics of a firm. This process might work for other service firms and even manufacturing firms, however to optimize the TRM process the specific setting of a firm should be taken into account and customized accordingly.

7 Contributions and recommendations

From the discussion and conclusions several theoretical contributions can be derived. This chapter presents the major theoretical contributions of this research. Subsequently, the most important managerial recommendations are given for practitioners implementing a TRM process within in the service industry.

7.1 Theoretical contributions

The potential of the TRM process had been largely demonstrated. However, it had mainly been applied within the manufacturing industry (Lee et al., 2012). In order to develop a successful TRM process it is widely recognized that the process should be adapted to the context and characteristics of a firm. Within the service industry only a handful of case studies had been performed. Although these case studies give an overview of what kind of roadmaps are applicable within the service industry, they neglect to give in-depth information regarding the variables of a service oriented firm which lead to a customization of the TRM process. By applying action research as the research strategy data is not collected retrospectively, but it captures the real-time development of the TRM process. A consequence is that a comprehensive report has been developed which describes the decision making process of the TRM team and the outcomes of the TRM process. Such an elaborated way of reporting about the development of a TRM process was not yet established.

From a TRM design point of view this thesis contributes to the current literature by creating transparency about the customization of a TRM process. Previous research had pointed out that the TRM approach is very flexible and that customization is necessary to adapt the process to the purpose and characteristics of a firm (Garcia & Bray, 1997; Groenveld, 1997; Phaal et al., 2004b; Lee & Park, 2005; Gerdsri et al., 2010). Checklists that describe what should be taken into account during the customization had been provided (Phaal et al, 2004b). However, guidance how to spot variables that demand customization and how one should adapt the process accordingly were absent. Within this thesis a model has been developed to fill this gap. The model includes several data collection methods by which variables can be spotted. A validation step has been incorporated to check whether a variable demands customization. Subsequently, it has been explained how the TRM architecture was adapted based on the identified variables. Whereas the current academic literature has been mainly focused on the customization of the architecture, this thesis has shown how to adapt the process design too. In-depth description of how the customization of the architecture and the process design has been handled helps scholars and practitioners with customization in the future. In addition, this thesis used four criteria to determine whether the TRM process suits the firm. The application of these criteria aid the transparency as every criterion has been dealt with in-depth. Therefore it can be said that the success of a TRM process is not solely dependent upon the success of the outcome as Gerdsri et al. (2009) state, but factors such as whether all relevant characteristics of a firm have been included and whether every workshop has added value to realize the initial goal are important to take into account during the evaluation.

The results of the study show that two service specific variables influenced the customization process of TRM process within a service oriented firm. First, the fading boundaries between services and products have been found within this firm which confirms the applicability of the PSS concept (White et al., 1999; Manzini & Vezzoli; 2003). The findings indicate that the fading boundaries subsequently influenced the TRM process within a service firm. An integrated product-service layer was implemented and has proven to be effective. Geum et al. (2011a) have attempted to implement the

same concept within TRM. The difference between the two approaches is that Geum et al. (2011a) did explicitly separate services from products. The findings of this thesis show that it is not a necessity to distinguish between products and services, but that it depends on the mindset and the use of terms within the company. Second, the idea that a contract of a service-oriented firm with its clients causes a short-term view can be confirmed based on the findings (Autor & Houseman, 2005; Lee et al., 2009). In addition to the confirmation of the current literature, the importance to take this into account for the TRM process has been demonstrated. The architecture of the product-service layer has been customized in such a way that a differentiation has been made been the user and the customer. Thereby features from both points of view are identified. In addition, it has been demonstrated that technology foresight was difficult to establish during this cycle. In this context Phaal et al. (2000) had indicated that unsuccessful TRM processes are caused by a lack of facilitation or training and when the right participants are not present during the workshops. The results of this thesis confirm these findings of Phaal et al. (2000), however an additional factor caused the lack of technology foresight, namely the nature of the service itself. The service for which the roadmap has been developed is a relatively straightforward one and therefore not many new technologies could be identified that impact this service.

7.2 Managerial recommendations

The results of this thesis gives guidance to practitioners who are faced with implementing a TRM process within a service oriented firm. The first paragraph presents recommendations about the architecture of the TRM process, while the latter paragraph is focused on the process design.

7.2.1 Architecture

The following practical recommendations are given specifically for managers who manage or want to manage a TRM process within a service-oriented firm.

- For a manager of a firm where the concepts of products and services are used interchangeably it is helpful to implement an integrated product-service layer in their TRM process. The main advantage of this is that the focus is on the core offerings of a company.
- Managers of service oriented firms where the user differs from the customer are encouraged to make to same differentiation in the product-service layer. The application of this distinction helps to identify diverse features on the roadmap.
- A manager of a service oriented firm is discouraged to implement a systems layer in their TRM process. The main reason for this is that the systems and architecture of a service are dynamic. This means that these change over time and that an assessment of how a feature influences the current architecture makes little sense as the architecture might look different at the time when the feature is implemented.

7.2.2 Process design

The following recommendations are applicable for managers of service-oriented firm, but some recommendations are more general and therefore also apply for other firms.

- Inexperienced TRM managers should take plenty of time to familiarize themselves and the TRM team with the concept of technology roadmapping. Planning a series of meetings in the preparation phase is a good way to discuss technology roadmapping.
- TRM practitioners should assign the responsibility of the TRM process to someone who is not directly responsible as product manager. This means that someone else facilitates the workshop whereby the product manager can contribute to the content of the workshop.
- Managers should conduct a briefing session before the start of a workshop series. This is a necessity to avoid unnecessary discussions during the workshops, to make sure that the premises of the process are known and the participants understand what is asked of them.
- Managers should keep the participants of the workshops the same where possible in every workshop. Continuity of participation increases the common understanding of the content of the roadmap which saves time explaining aspects of the roadmap during the workshops.
- Managers should reserve four hours to complete the product-service workshop. If the gap analysis is also conducted during this workshop an additional two hours are recommended.
- Managers should make sure that during the product-service workshop the identified features are on the same level of abstraction. This is essential for a proper prioritization and identification of technologies in the following workshop. The moderator of the workshop should be aware and capable of guiding this process.
- Managers should reserve a few days in between each workshop to process the outcome of the previous and to prepare the following workshop. Especially in between the product-service and technology workshop the TRM team should have at least five days.

7.3 Future research

Besides managerial recommendations there are several opportunities for future academic research in the field of technology roadmapping. First, a systemic customization framework has not been developed yet. Guidelines are available which state for what indicators one should look. This thesis adopted a customization framework that incorporated multiple methods, however it remained uncertain whether a variable really demands customization. A possible first step towards a proper customization process is to conduct empirical research by looking retrospectively which variables have had a significant effect on customization. Second, additional studies that incorporate an action research approach can enhance the insights into technology roadmapping. The advantage of action research is that it does not rely on the memory of respondents. Furthermore, researchers can design and test frameworks that they have designed themselves. By obtaining an understanding of the choices that the researcher makes in the customization process would be both practically and theoretically helpful. Third, technology roadmapping within the service industry is still an underexposed research topic. The service industry is becoming increasingly relevant because of the shift towards services. Additionally, the integration of products and services raised a lot of awareness. Exploring the integration of topics such as PSS within technology roadmapping is therefore very interesting. It would even be possible to explore whether a TRM process that encompasses the PSS concept can be implemented in a manufacturing firm that experiences a *servitization* of its products. More in-depth studies are necessary to obtain a better understanding of these phenomena.

7.4 Reflection

Using an action research approach has certainly been a challenge. The combination of theoretical with practical objectives demands discipline and structure from the researcher. The outcome of the TRM process is satisfying, especially taking into account that it was the first time that such a process has been implemented in the firm and that there was little practical expertise present regarding the concept of TRM. However, reflecting on the process itself several changes would have made process better. As explained previously the outcome would have been better when a briefing sessions was held before the workshop series started. In addition, in retrospect the planned systems workshop would not have had much added value for the roadmap and we have spent a few meetings on preparing this workshop. This time would have been better spent on preparing the technology workshops. Certainly the process has not been perfect, but by implementing such a process new insights are obtained which can improve the process in the future.

Looking back at the implemented research design it can be stated that the adoption of an action research approach has been useful from a theoretical and practical perspective. From a practical perspective it gives insights into the important choices that have to be made while customizing for example. From a theoretical perspective it increases the understanding of implementing a TRM process within a service oriented firm. The use of a longitudinal case study method would have been interesting too, but from a practical perspective not realizable because a firm employs someone for the benefit of the firm. Therefore action research is an appropriate method to incorporate both perspectives.

8 References

Abernathy, W., & Utterback, J. (1978). Patterns of industrial innovation. *Technology Review, 80*(7), 40-47.

Aghion, P., Bloom, N., Blundell, R., Griffith, R., & Howitt, P. (2005). Competition and Innovation: An Inverted-U Relationship. *Quarterly Journal of Economics, 120*(2), 701-728.

Aguinis, H. (1993). Action research and scientific method: Presumed discrepancies and actual similarities. *Journal of Applied Behavioral Science, 29*(4), 416-431.

Albright, R.E., & Kappel, T.A. (2003). Roadmapping in the corporation. *Research Technology Management, 46*(2), 31-40.

An, Y., Lee, S., & Park, Y. (2008). Development of an integrated product-service roadmap with QFD: a case study on mobile communications. *International Journal of Service Industry Management, 19*(5), 621-638.

Autor, D.H., & Houseman, S.N. (2005). Do temporary help jobs improve labor market outcome for low-skilled workers? Evidence from random assignments. *Quarterly Journal of Economics, 116*(4), 1409-1448.

Avison, D.E., & Wood-Harper, A.T. (1991). Conclusions from action research: the multiview experience. In M.C. Jackson et al. (Eds.). *Systems Thinking in Europe,* Plenum Press, New York.

Baarda, B., de Goede, M., & Teunissen, J. (2005). *Basisboek Kwalitatief Onderzoek, Handleiding voor het Opzetten en Uitvoeren van Kwalitatief Onderzoek.* Groningen: Wolters-Noordhoff.

Babbie, E. (2007). *The Practice of Social Research.* Belmont: Thomson Wadsworth.

Baines, T.S., Lightfoot., H.W., Evans, S., Neely, A., Geenough, R., Peppard, J., Roy, R., Shebab, E., Braganza, A., Tiwari, A., Alcock, J.R., Angus, J.P., Bastl, M., Cousens, A., Irving, P., Johnson, M., Kingston, J., Lockett, H., Martinez, V., Michele, P., Tranfield, D., Walton, I.M., Wilson, H. (2007). State-of-the-art in product-service systems. *Journal of Engineering Manufacture, 21*(10), 1543-1552.

Barras, R. (1990). Interactive innovation in financial and business services: The vanguard of the service revolution. *Research Policy, 19*(3), p. 215-237.

Baskerville, R.L., & Wood-Harper, A.T. (1996). A critical perspective on action research as a method for information systems research. *Journal of Information Technology, 11*(3), 235-246.

Baxter, P., & Jack, S. (2008). Qualitative case study methodology: Study design and implementation for novice researchers. *The Qualitative Report, 13*(4), 544-559.

Berry, L.L., Shankar, V., Parish, J.T., Cadwallader, S., & Dotzel, T. (2006). Creating new market through service innovation. *MIT Sloan Management Review, 47*(2), 56-63.

Bitner, M.J., Brown, S.W., & Meuter, M.L. (2000). Technology infusion in service encounters. *Journal of the Academy of Marketing Science, 28*(1), 138-149.

Blichfeldt, B.S., & Andersen, J.R. (2006). Creating a wider audience for acion research: learning from case-study research. *Journal of Research Practice, 2*(1), 1-15.

Checkland, P., & Holwell, S. (1998). Action research: Its nature and validity. *Systemic Practice and Action Research, 11*(1), 9-21.

Cho, C., & Lee, S. (2011). Taxonomy of technology roadmaps in service areas. *IEEE International Technology Management Conference*, 462-467.

Coghlan, D. (2003). Practitioner research for organizational knowledge: mechanistic- and organistic-oriented approaches to insider action research. *Management Learning, 34*(4), 451-463.

Coombs, R., & Miles, I. (2000). Innovation, measurement and services. In Metcalfe, J.S., & Miles, I. (Eds*), Innovation systems in the Service Economy. Measurement and Case Study Analysis* (85-103). Boston, MA: Kluwer Academic.

Cosner, R.R., Hynds, E.J., Fusfeld, A.R., Loweth, C.V., Scouten, C., & Albright, R. (2007). Integrating roadmapping into technical planning. *Research Technology Management, 50*(6), 31-48.

Coughlan, P., & Coghlan, D. (2002). Action research for operations management. *International Journal of Operations & Production Management, 22*(2), 220-240.

Creswell, J.W. (2009). *Research Design: Qualitative, Quantitative, and Mixed Approaches.* London: Sage Publications.

Creswell, J.W., & Miller, D.L. (2000). Determining validity in qualitative inquiry. *Theory Into Practice, 39*(3), 124-130.

Cunningham, J.B. (1993). *Action Research and Organizational Development*. Westport, CT: Praeger.

Daim, T.U., & Oliver, T. (2008). Implementing technology roadmap process in the energy services sector: A case study of a government agency. *Technology Forecasting & Social Change, 75*(5), 687-720.

Davenport, T. (1993). *Process innovation: Reengineering work through information technology*. Boston: Harvard Business School Press.

Davison, R.M., Martinsons, M.G., & Kock, N. (2004). Principles of canonical action research. *Information Systems Journal, 14*(1), 65-86.

De Jong, J.P.J., Bruins, A., Dolfsma, W., & Meigaard, J. (2003). Innovation in service firms explored: what, how and why? Strategic Study, EIM Business & Policy Research, Zoetermeer, The Netherlands.

De Vries, E.J. (2006). Innovation in services networks or organizations and in the distribution of services. *Research Policy, 35*(7), 1037-1051.

Den Hertog, P. (2000). Knowledge-intensive business services as co-producers of innovation. *International Journal of Innovation Management, 4*(4), 491-528.

Drejer, I. (2004). Identifying innovation in surveys of services: A Schumpeterian perspective. *Research Policy, 33*(3), 551-562.

Droege, H., Hildebrand, D., & Forcada, A.H. (2009). Innovation in services: present findings, and future pathways. *Journal of Service Management, 20*(2), 131-155.

Domberger, S. & Jensen, P. (1997). Contracting out by the public sector: Theory, evidence, prospects. *Oxford Review of Economic Policy, 13*(4), 67-78.

Dorfman, N. (1983). Route 128: The development of a regional high technology economy. *Research Policy, 12*(6), 299-316.

EIRMA. (1997). Technology roadmapping – delivering business vision. Working group report, *European Industrial Research Management Association,* Paris, n.52.

Eisenhardt, K.M. (1989). Building theories from case study research. *Academy of Management Review, 14*(4), 532-550.

Evangelista, R. (2000). Sectoral patterns of technological change in services. *Economics of Innovation and New Technology, 9*(3), 183-222.

Fenwick, D., Daim, T.U., & Gerdsri, N. (2009). Value driven technology road mapping (VTRM) process integrating decision making and marketing tools: Case of Internet security technologies. *Technological Forecasting & Social Change, 76*(8), 1055-1077.

Fitzsimmons, J.A., & Fitzsimmons, M.J. (2000). *New Service Development: Creating Memorable Experiences*. Thousand Oaks, CA: Sage.

Fitzsimmons, J.A., & Fitzsimmons, M.J. (2001). *Service Management (3rd Edition).* New York: McGraw-Hill.

Fouskas, K.G., Giaglis, G.M., Kourouthanassis, P.E., Karnouskos, S., Pitsillides, A., & Stylianou, M. (2005). A roadmap for research in mobile business. *International Journal of Mobile Communications, 3*(4), 350-373.

Gadrey, J., Gallouj, F., & Weinstein, O. (1995). New modes of Innovation: how services benefit industry. *International Journal of Service Industry Management, 6*(3), 4-16.

Gann, D.M., & Salter, A.J. (2000). Innovation in project-based, service-enhanced firms: The construction of complex products and systems. *Research Policy, 29*(7-8), 955-972.

Gallouj, F., & Weinstein, O. (1997). Innovation in services. *Research Policy, 26*(4-5), 537-556.

Gallouj, F. (1998). Innovating in reverse: services and the reverse product cycle. *European Journal of Innovation Management, 1*(3), 123-138.

Gallouj, F. (2000). Beyond technological innovation: Trajectories and varieties of services innovation. In: Boden, M., & Miles, I, *Services and the Knowledge-Based Economy* (129-145). London: Continuum.

Galvin, R. (1998). Science roadmaps. *Science, 280 (5365), 803.*

Garcia, M.L., & Bray, O.H. (1997). *Fundamentals of technology roadmapping*. Albuquerque, NM: Sandia National Laboratories.

Gerdsri, N., Assakul, P., & Vatananan, R.S. (2010). An activity guideline for technology roadmapping implementation. *Technology Analysis & Stategic Management, 22*(2), 229-242.

Geum, Y., Kang, D., Lee, H., & Park, Y. (2010). Technology interfaces in product-service integration: Concept and typology. *PICMET '10 – Portland International Center for Management of Engineering and Technology, Proceedings – Technology Management for Global Economic Growth, art. No. 5603400, 9-15.*

Geum, Y., Lee, S., Kang, D., & Park, Y. (2011a). Technology roadmapping for technology-based product-service integration: A case study. *Journal of Engineering and Technology Management*, 28(3), 128-146.

Geum, Y., Lee, S., Kang, D., & Park, Y. (2011b). The customisation framework for roadmapping product-service integration. *Service Business, 5*(3), 213-236.

Geum, Y., & Park, Y. (2011). Designing the sustainable product-service integration: A product-service blueprint approach. *Journal of Cleaner Production, 19*(14), 1601-1614.

Goedkoop, M., van Haler, C., te Riele, H., & Rommers, P. (1999). Product service-systems, ecological and economic basics. *Report for Dutch Ministries of Environment (VROM) and Economic Affairs (EZ).*

Groenveld, P. (2007). Roadmapping integrates business and technology. *Research Technology Management, 40*(5), 48-55.

Grønhaug, K., & Olson, O. (1999). Action research and knowledge creation: merits and challenges. *Qualitative Market Research: An International Journal, 2*(1), 6-14.

Gustafsson, A., & Johnson, M.D. (2003). *Competing in a service economy*. San Francisco, CA: Jossey-Bass.

Hefetz, A. & Warner, M.E. (2011). Contracting of public delivery? The importance of service, market, and management characteristics. *Journal of Public Administration Research and Theory, 22*(2), 289-317.

Hipp, C., & Grupp, H. (2005). Innovation in the service sector: The demand for service-specific innovation measurement concepts and typologies. *Research Policy, 34*(4), 517-535.

Howells, J. (2006). Where to from here for services innovation?. *Knowledge Intensive Services Activities (KISA) conference*, March, Sydney.

Iversen, J.H., Mathiassen, L., & Nielsen, P.A. (2004). Managing risk in software process improvement: An action research approach. *MIS Quarterly, 28*(3), 395-433.

Johnson, R.B. (1997). Examining the validity structure of qualitative research. *Education, 118*(2), 282-292.

Johnson, S.P., Menor, L.J., Roth, A.V., & Chase, R.B. (2000). A critical evaluation of the new service development process: integrating service innovation and service design. In Fitzsimmons, J.A., & Fitzsimmons, M.J. (Eds.), New Service Development – Creating Memorable Experiences. Thousand Oaks, CA: Sage.

Kameoka, A., Nakamura, K., Fujuwara, T., & Kamada, N. (2006). “Services science” and services layer added strategic technology roadmapping. *Portland International Conference on Management of Engineering and Technology, 4*(art no. 4077592), 1956-1961.

Kang, K.C., Cohen, S.G., Hess, J.A., Novak, W.E., & Peterson, A.S. (1990). Feature-oriented domain analysis (FODA) feasibility study. *Technical report, CMU/SEI-90TR-21, November.*

Kappel, T.A. (2001). Perspectives on roadmaps: How organizations talk about the future. *The Journal of Product Innovation Management, 18*(1), 39-50.

Kim, C., Choe, S., Choi, C., & Park, Y. (2008). A systematic approach to new mobile service creation. *Expert Systems with Applications, 35*(3), 762-771.

Kindström, D., & Kowalkowski, C. (2009). Development of industrial service offerings: a process framework. *Journal of Service Management, 20*(2), 156-172.

Kock, N. (2004). The three threats of action research: a discussion of methodological antidotes in the context of an information systems study. *Decisions Support Systems, 37*(2), 265-286.

Kostoff, R.N., Boylan, R., & Simons, G.R. (2004). Disruptive technology roadmaps. *Technology Forecasting & Social Change, 71*(1-2), 141-159.

Kostoff, R.N., & Schaller, R.R. (2001). Science and technology roadmaps. *IEEE Transactions on Engineering Management, 48*(2), 132-143.

Krueger, R.A. (1988). *Focus Groups: A Practical Guide for Applied Research.* CA: Sage Publications, Inc Newbury Park.

Lee, R.P., Ginn, G.O., & Naylor, G. (2009). The impact of network and environmental factors on service innovativeness. *Journal of Services Marketing, 23*(6), 397-406.

Lee, J.H., Kim, K., Phaal, R. (2012). An analysis of factors improving technology roadmap credibility: A communications theory assessment of roadmapping processes. *Technology Forecasting & Social Change, 79*(2), 263-280.

Lee, J.H., & Park, Y. (2005). Customization of technology roadmaps according to roadmapping purposes: Overall process and detailed modules. *Technological Forecasting & Social Change, 72*(5), 567-583.

Lewin, K. (1951). Action research and minority problems. *Journal of Social Issues, 2*(4), 34-46.

Linton, J.D., & Walsh, S.T. (2008). A theory of innovation for process-based innovations such as nanotechnology. *Technological Forecasting & Social Change, 75*(5), 583-594.

Manzini, E., & Vezolli, C. (2003). A strategic design approach to develop sustainable product service systems: examples taken from the ‘environmentally friendly innovation. *Journal of cleaner production, 11*(8), 851-857.

Mays, N., & Pope, C. (1995). Qualitative research: Rigour and qualitative research. *British Medical Journal, 311*(6997), 109-112.

McFeeley, B. (1996). IDEAL*: A user's guide for software process improvement*. Pittsburg, PA: Software Engineering Institute.

McKay, J., & Marshall, P. (1999). A framework for rigour in action research*. Proceedings of the American Conference on Intermation Systems,* Lincoln Business School, Lincoln, July.

McKay, J., & Marshall, P. (2001). The dual imperatives of action research. *Information Technology & People, 14*(1), 46-59.

Menor, L.J. (2000). *An empirical investigation of new service development competence and performance*. Ph.D dissertation, University of North Carolina, Chapel Hill, NC.

Menor, L.J., & Roth, A.V. (2007). New service development competence in retail banking: construct development and measurement validation. *Journal of Operations Management, 25*(4), 825-846.

Menor, L.J., Tatikonda, M.V., & Sampson, S.E. (2002). New service development: Areas for exploitation and exploration. *Journal of Operations Management, 20*(2), 135-157.

Miozzo, M., & Soete, L. (2001). Internationalization of services: A technological perspective. *Technological forecasting and social change, 67*(2-3), 159-185.

Moehrle, M.G., Isenmann, R., & Phaal, R. (2013). Basics of technology roadmapping. In Moehrle, M.G., Isenmann, R., & Phaal, R (Eds). *Technology Roadmapping for Strategy and Innovation (*1-10). Berlin: Springer Berlin Heidelberg.

Nakamura, K., Aoki, T., Hosoya, M., Fukuzawa, Y., & Kameoka, A. (2006). A roadmapping practice for enhancing the Japanese engineering service towards advanced IT network age. *Proceedings of the 15th International Conference on Management of Technology*. Bejing.

Nightingdale, P. (2003). Innovation in financial services infrastructure in Shavinina. In Shavinina, L.V. (Ed.), *The International Handbook of Innovation (529-547)*. Oxford: Elsevier.

Nijssen, E.J., Hillebrand, B., Vermeulen, P., & Kemp, R.G.M. (2006). Exploring product and service innovation similarities and differences. *Research in Marketing, 23*(3), 241-251.

Oke, A. (2007). Innovation types and innovation management practices in service companies. *International Journal of Operations & Production Management, 27*(6), 564-587.

Petrick, I.J., Echols, A.E. (2004). Technology roadmapping in review: A tool for making sustainable new product development decisions. *Technology Forecasting & Social Change, 71*(1-2), 81-100.

Phaal, R., Farrukh, C.J.P., Mitchell, R., & Probert, D.R. (2003). Starting-up roadmapping fast. *Research Technology Management, 46*(2), 52-58.

Phaal, R., Farrukh, C.J.P., & Probert, D.R. (2000). Fast-start technology roadmapping, *Proceedings of the 9th International Conference of Management of Technology (IAMOT 2000)*, 21-25th February, Miami.

Phaal, R., Farrukh, C.J.P., & Probert, D.R. (2001). Characterisation of technology roadmaps: Purpose and format. *Portland International Conference on Management of Engineering and Technology (PICMET 2001), 2*, 367-374.

Phaal, R., Farrukh, C.J.P., & Probert, D.R. (2004a). Technology roadmapping – A planning framework for evolution and revolution. *Technology Forecasting & Social Change, 71*(1-2), 5-26.

Phaal, R., Farrukh, C.J.P., & Probert, D.R. (2004b). Customizing roadmapping. *IEEE Engineering Management Review, 32*(3), 80-91.

Phaal, R., Farrukh, C.J.P., & Probert, D.R. (2005). Developing a technology roadmap system. *Paper presented at the Portland International Center of Management of Engineering and Technology (PICMET),* July 31 – August 4, 2005, Portland, Oregon, USA.

Phaal, R., & Muller, G. (2009). An architectural framework for roadmapping: Towards visual strategy. *Technology Forecasting & Social Change, 76*(1), 39-49.

Pilat, D. (2000). No longer services as usual. *OECD Observer, 223*, 52-54*.*

Probert, D., & Radnor, M. (2003). Frontier experiences from industry-academia: consortia corporate roadmappers create value with product and technology roadmaps. *Research Technology Management, 46*(2), 27-30.

Ray, A.W., & Ray, J.J. (2006). Strategic benefits to SMEs from third party web services: An action research analysis. *Journal of Strategic Information Systems, 15*(4), 273-291.

Rinne, M. (2004). Technology roadmaps: Infrastructure for innovation. *Technology Forecasting & Social Change, 71*(1-2), 67-80.

Shadish, W.R., Cook, T.D., & Campbell, D.T. (2002). *Experimental and Quasi-Experimental Designs for Generalized Causal Inference.* Boston: Houghton Mifflin Company.

Shugan, S.M. (1994). Explanation for service growth. In Oliver, R., & Rust, R. (Eds), *Service Quality*. Newbury Park, CA: Sage.

Sirilli, G., & Evangelista, R. (1998). Technological innovation in services and manufacturing: Results from Italian surveys. *Research Policy, 27*(9), 882-899.

Sundbo, J., Orfila-Sintes, F., & Soerensen, F. (2007). The innovative behavior of tourism firms – comparative studies of Denmark and Spain. *Research Policy, 36*(1), 88-106.

Susman, G.I., & Evered, R.D. (1978). An assessment of the scientific merits of action research. *Administrative Science Quarterly, 23*(4), 582-603.

Thomke, S.H. (2003). R&D comes to services: bank of america's pathbreaking experiments. *Harvard Business Review, 81*(4), 70-79.

Thompson, L. (2003). Improving the creativity of organizational work groups. *Academy of Management Executive, 17*(1), 96-111.

Tuominen, A., & Ahlqvist, T. (2010). Is the transport system becoming ubiquitous? Socio-technical roadmapping as a tool for integrating the development of transport policies and intelligent transport systems and services in Finland. *Technology Forecasting & Social Change, 77*(1), 120-134.

Van Aken, J.E., Berends, H., & van der Bij, H. (2006). *Problem-solving in Organizations – A Methodological Handbook for Business Students.* Cambridge: Cambridge University Press.

Van Riel, A.C.R., Lemmink, J., & Ouwersloot, H. (2004). High-technology service innovation succes: A decision-making perspective. *Journal of Product Innovation Management, 21*(5), 348-359.

Vatananan, R.S., & Gerdsri, N. (2004). An analystical approach to assess the current state of a roadmap. *IEEE.*

Vojak, B.A., & Chambers, F.A. (2004). Roadmapping disruptive technical threats and opportunities in complex, technology-based subsystems: The SAILS methodology. *Technology Forecasting & Social Change, 71*(1-2), 121-139.

Wells, R., Phaal, R., Farrukh, C., & Probert, D. (2004). Technology roadmapping for a service organization. *Research Technology Management, 47*(2), 46-51.

White, A.L., Sloughton, M., & Feng, L. (1999). *Servicing: The Quiet Transition to Extended Product Responsibility*. Boston, Tellus Institute

Yin, R.K. (2003). *Case Study Research: Design and Methods (2nd ed.).* Thousand Oaks, CA: Sage.

9 Appendices

9.1 Appendix A: Overview of activities TC

The main task for TC is to collect toll from trucks as efficient as possible and transfer the collected toll to the government. The creation of the satellite-based system enables the company to charge toll without stopping the trucks, so traffic jams before toll collection gates can be avoided. A minimal burden is placed on the truckers. This service is enabled by several processes which are pieces of the whole service. Figure 13 shows a brief overview of these processes.

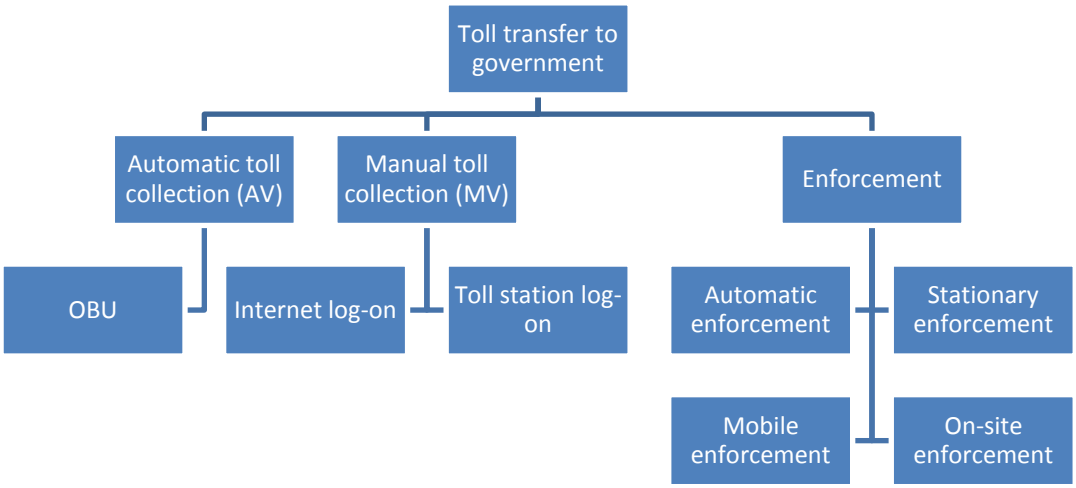

Figure 14: Activity overview TC

9.1.1 Automatic toll collection

The first option is the automatic log-on option. Truckers receive an On-Board Unit (OBU) whereby their traces are tracked through a satellite system. The OBU identifies the route which the vehicle is travelling and automatically calculates usage charges with current toll rates. The toll information of the OBU is subsequently encrypted and transmitted to TC through wireless mobile communication. Truckers are charged per driven kilometer on toll-liable roads in Germany and receive a monthly invoice. Figure 14 shows a brief overview of automatic log-on activity.

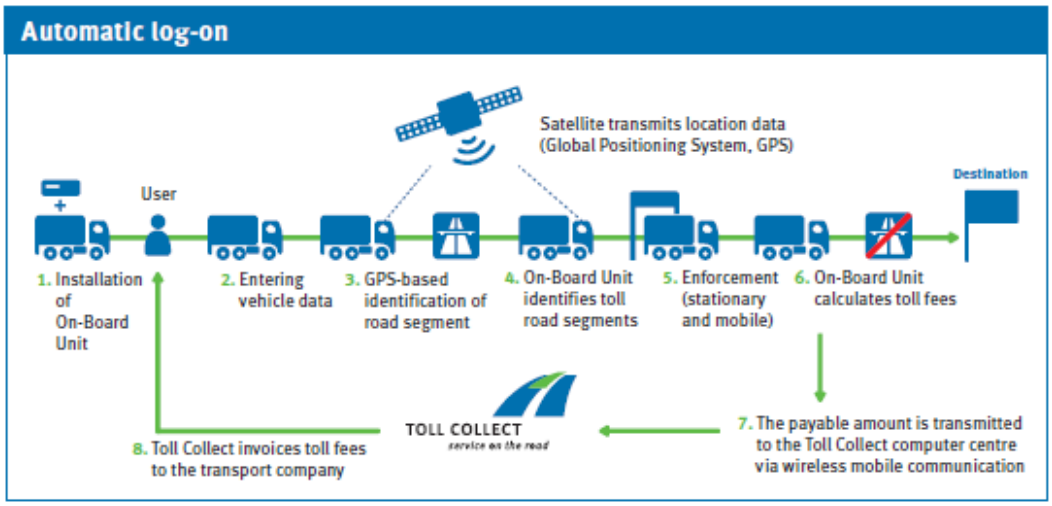

Figure 15: Automatic toll collection

9.1.2 Manual toll collection

The manual toll collection activities exist out of two different options. The first option is the manual log-on option. Users manually log-on via the Internet up to three days before the start of their journey. The user can either select an already registered vehicle, or another vehicle (e.g. a rental truck). The system calculates the shortest possible route in the network is generated when the user inserts the start and ending point of the route. This route can be accepted or modified to own preferences. When proper route has been accepted the user books it and receives a log-on receipt. Figure 15 shows a brief overview of the activity.

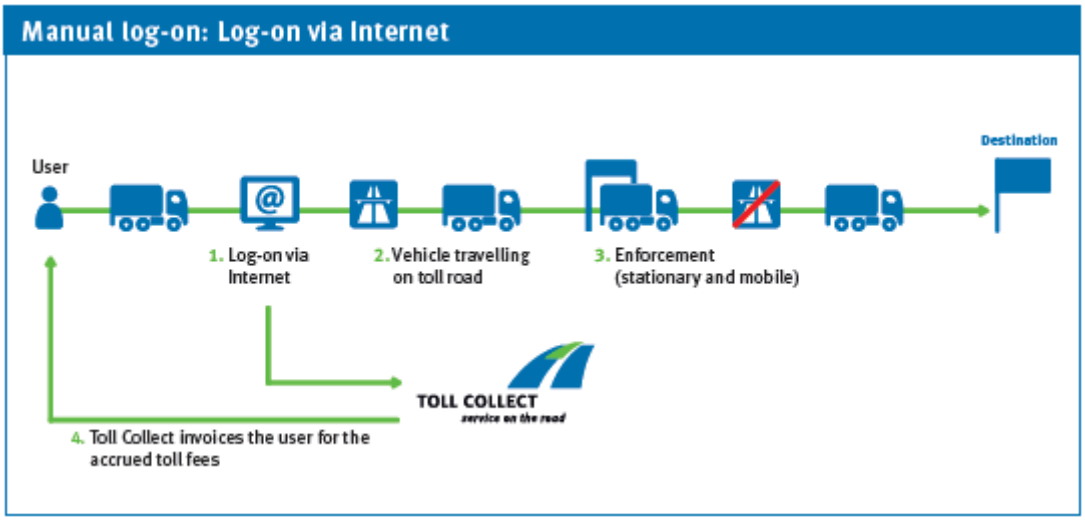

Figure 16: Manual toll collection via internet log-on

The second option encompasses a log-on at a toll-station terminal. This system is similar to a purchasing a ticket from a vending machine. Users insert all relevant vehicle data along with the starting time, starting location and destination. The system then calculates the shortest route within the roll road network. Users can modify the route again and when he or she is satisfied the route can be confirmed. The system automatically calculates the maximum route completion time to prevent multiple use of a route with a single log-on. Finally, the driver receives a log-on receipt. Figure 16 shows a brief overview of the activity.

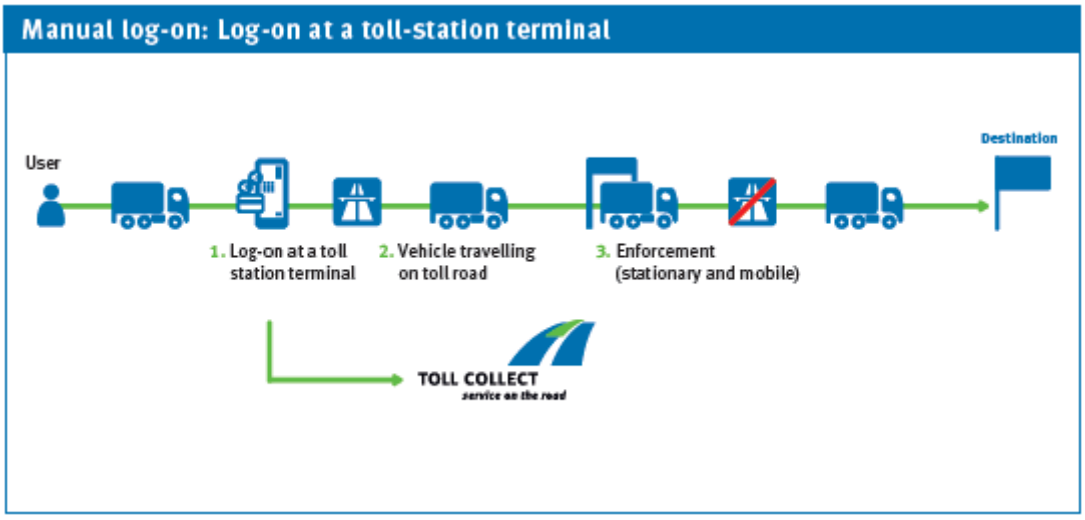

Figure 17: Manual toll collection via toll-station log-on

9.1.3 Enforcement

In order to ensure that every toll-liable user pays toll an enforcement system which monitors traffic has been set up. These tasks are not entirely carried out by TC, but are shared with the Federal Office of Goods Transportation. Enforcement is carried through four different activities: automatic enforcement, stationary enforcement, mobile enforcement and on-site enforcement.

Automatic enforcement is done through the installation of 300 permanently installed enforcement gantries. These record approaching trucks and check whether trucks that are toll-liable are logged onto the system. The number plates of all other vehicles are read out and compared with the data stored at the TC computer centre. If no log-on, in what way whatsoever, is detected TC conducts an investigation. If necessary, retroactive payment is demanded. This information is also transferred to the government. If vehicles have been logged-on correctly, the data is deleted.

Stationary enforcement encompasses the transfer of information regarding potential toll violators to the government. Officials of the government can stop suspected vehicles for a detailed inspection. This allows the government to immediately clarify the situation, and where necessary, impose fines.

Mobile enforcement is done through monitoring vehicles 24 hours a day to ensure that tolls are paid correctly. This is done by the government who installed 300 mobile teams. These teams operate in a similar fashion as the automatic enforcement. Information of the toll collection database from TC is compared with data of toll-liable vehicles. If discrepancies emerge, the trucks can be stopped to clarify the matter.

On-site enforcement regards spot checks at transport companies throughout Germany. The checks are partly done randomly, but also if there is suspicion that toll in not paid correctly. This is carried out by the government.

The main task for TC is installing the necessary technology into the vehicles of the government which execute the enforcement. The technology includes both software and hardware. The government gets access to the databases of TC in order to compare it with identified toll-liable vehicles. TC also provides the enforcement gantries and the equipment which is installed into the vehicles of the government.

9.2 Appendix B: Definitions of technology roadmapping

Author(s)	Definition
Garcia & Bray (1997)	A document created as a result of technology roadmapping process
Kostoff & Schaller (2001)	An auxiliary tool to concrete the links between the research program, development program, objective capacity and requirements thereof
Kappel (2001)	Documents that recognize the key defining parameters of the markets, products, and technologies for one part of the business.
Probert & Radnor (2003)	Participants' views to envision the ways to fulfill their goals
Rinne (2004)	A map that shows the direction of technology and development of products using it
Phaal (2004a)	A flexible method widely applicable in industry to help establishment of plans that are strategic and of wide scope

Table 13: Definitions of technology roadmapping

9.3 Appendix C: Interview protocol

Preparation

Participants

- Do you think you have been informed well enough about the roadmapping process before the workshops began?

Workshops

TRM team

During the preparation some decisions have been made that have influenced the process.
In an early stage the idea was to keep the process in PPM internally.

- Why was this decided?
- Who decided this?
- Do you think this has been a good decision?

It was furthermore decided that a TC employee did the mediation of the workshop.

- Why was this decided?
- Who decided this?
- Do you think this has been a good decision?

General

- How do you think the workshops went in general?
- How would you rate the participation of the participants during the workshops?
- What was the most difficult part of the workshops?
- During the first workshop we used an individual prioritization method.
- What do you think of this method?
- Should the prioritization be done differently in the future?
- How?
- During the third and fourth workshop the focus was on identifying technologies.
- Do you think these workshops are valuable?
- Should they be done in the future?
- How would you rate quality of the ideas during the workshops?
- Are there any ideas that came out of the workshops that had not been identified previously?
- Would you have done anything differently during the workshops?

Outcome

The main objective of this project was to “develop a technology roadmapping process which integrates and aligns current product planning processes with technology and market foresight”.

- To what extent do you think this has been realised?
- How useful is this roadmapping method is for PPM?
- How valuable do you think the content of the roadmap is?
- How valuable do you think the roadmap is for SUE?
- Another goal of the method is to create knowledge spill-overs and remove barriers between different departments. To what extent do you think this has been achieved?
- We have identified relatively few new technologies in the roadmap. What do you think caused this?
- How do you see the role of the different departments (SUE, PPM, MD) in this process? Should they be involved for next cycles too?
- Are there any experts or departments that you would like to be involved with the process in the future?

Integration

- Do you think the roadmap should be used within TC?
- Why (not)?
- How do you think should it be used?
- Do you think this roadmapping method should be carried out too for the other product-families?
- Should it be done again in future for MV?
- How often?
- Do you think PPM can do this TRM process on its own when the input of SUE has been delivered?
- Who do you think should have the ownership of this process?
- What processes in TC could deliver input for this roadmapping process?
- For what processes could this roadmapping process be used as input for?
- For the integration of the roadmapping process within TC these are then the processes which it should be aligned with?

General questions about TC

- Do you think the contract with the BAG has influence on how TC prepares itself for the future?
- In what way?
- Is it difficult for TC to think of plans that go beyond the current contract?
- How would you characterise the hierarchical structure within TC?
- How do you see the barriers between the different departments in TC?
- Do you think this influences the way TC prepares itself for the future?

9.4 Appendix D: Log of meetings

Date	Time	Position	Main outcome
23-11-2012	14:30-15:00	Department leader SUE	• Establish the objective of the SUE department for the TRM process
		Researcher	• Establish agreement on the first initial TRM process design
			• It became apparent that several steps of the initiation phase already had been established (awareness, value)
23-11-2012	15:00-17:00	Department leader PPM	• Explanation of interviewee's view on roadmaps
		Researcher	• Articulation of the objectives for the process by the PPM department
7-12-2012	14:00-15:30	Department leader PPM	• Terms products and services are used interchangeably within TC
		Researcher	
12-12-2012	14:00-15:00	Researcher	• Delivery of the RUN2018 documentation
		External consultant	• Delivery of system architecture documentation
20-12-2012	13:00-14:00	Department leader PPM	
		Researcher	
17-1-2013	10:00-11:00	Researcher	• Align the thoughts of the roadmapping team, both theoretical and practical
		External consultant	• Global theoretical framework has been agreed upon
		Product manager	• Agreement that the current definitions do not fit with the TRM process
			• Agreement that the mediation techniques should be further explored
21-1-2013	14:00-15:00	Researcher	• Parameters will be judged during the workshop, but on a global level
		External consultant	• List of potential participants for the different workshop has been drawn
		Product manager	
		Department leader PPM	
22-1-2013	13:30-15:00	Researcher	• Obtained insight into the product-planning process of the EF system
		External consultant	• The roadmaps have similarities which is good for consistency of the roadmaps
		Product manager	
		Product manager	
23-1-2013	10:00-11:00	Researcher	• Use this TRM process as idea-management
		External consultant	
		Product manager	
		Strategy portfolio manager	
23-1-2013	13:00-15:00	10 product managers	• Market driver identified
			• Include suppliers in the system layer

25-1-2013	10:00-11:00	Researcher	• Establishment where the TRM process fits in the current product management process
		External consultant	
		Product manager	
28-1-2013	11:00-12:15	Researcher	• This list of participants has been decided upon.
		External consultant	• There is a list of prioritized market and business drivers at the SUE department
		Product manager	• Use global TC prioritization for segmentation priority
		Product manager	
29-1-2013	11:00-12:00	Researcher	• Creation of a framework that enables differentiated prioritization of different product families
		External consultant	• Clarification that a feature is a part of the satisfaction of a market or business driver
		Product manager	• A preparation for each workshop is needed to establish the current state of (1) market/business driver (2) possible product features (3) possible technologies
30-1-2013	11:00-12:15	Researcher	• Established set of definitions for: product feature, product, service, product-service system
		External consultant	• Determined the prioritization method
		Product manager	• Include the prioritization of the SUE department
			• "RUN2018" should not be included as a "product-family", but it should be taken into account during WS5
			• An "umbrella" theme will be used to group individual features
31-1-2013	9:25-10:45	Researcher	• Prioritization based on specific technology not relevant for TC
		External consultant	• Instead, determining to what extend the current MV process will be affected will be explored
		Product manager	• Established global agenda for workshop 3
1-2-2013	9:30-10:50	Researcher	• No standard set of drivers available
		Product manager	• Include features/drivers that go beyond the term of the contract
		Strategy portfolio manager	• MV product family used a first test-run of the TRM methodology
		Leader strategic planning	• Align current SUE and PPM cycles in order to include up-to-date information
4-2-2013	14:40-15:55	Researcher	• Created awareness of strategic scenario's that could serve as input
		External consultant	• Different prioritization method
		Product manager	• Shuffle of the workshops

5-2-2013	14:40-15:55	Researcher	• Input of scenario's, and macro data of AV, MV and EF will be used for WS1
		External consultant	• After WS2 an assessment should be made whether features fit in legal framework
		Product manager	• WS3 will only focus on new technologies, and WS4 will look at which current technologies are need / need to be adjusted
5-2-2013	16:30-17:10	Researcher	• Assess gaps or hurdles of each feature (technology, organisational/implementation)
		External consultant	• Possible approach is a SWOT analysis
		Product manager	• Step from technology to roadmapping too large, therefore a pre-study was proposed
		Product manager MV	
6-2-2013	10:35-11:15	Researcher	• Include SUE department as a participant
		Product manager	• Guideline for every workshop will be created
			• Establishment of a meeting in which is discussed what is expected from the mediator
8-2-2013	10:35-11:00	Researcher	• Briefing of the mediator
		Product manager	• Agreement on WS1
			• Clarified what was meant with the term issues
13-2-2013	10:35-12:30	Researcher	• Top management stick to the content of the contract to a very large extent
		External consultant	• SUE uses scenario analysis to look in to the future
		Product manager	• Use and document assumptions
		Product manager	• Proposal of stage-gate between WS1 and WS2
		Leader strategic planning	
13-2-2013	15:05-16:30	Researcher	• Established mathematics for WS1 and WS2
		External consultant	• Focus of challenges on users and customer
		Product manager	• Product strategy in agenda
			• Ask SUE to give an informational base during WS1
18-2-2013	10:00-13:00	9 people present	WS1
18-2-2013	16:30-18:15	Researcher	• Although strategic context was important, this should be clear up front through a briefing session
		External consultant	• Market drivers (at least first 3) have been agreed upon by SUE
		Product manager	• Prioritization differed to a great extent for some drivers
			• No business drivers identified, discuss with SUE
			• Present MV product strategy in WS2
19-2-2013	16:00-16:45	Researcher	• Tonnageabsenkung more important than EETS relatively for MV

		External consultant	• Challenges used as documents that participants can use during the workshop
		Product manager	• Validation can be best done with the product manager of MV
20-2-2013	08:45-09:45	Researcher	• Market drivers reflect the view of SUE
		Leader strategic planning	• Agreement on using "innovation" as a business driver
20-2-2013	15:00-18:00	10 people present	WS2
21-2-2013	16:00-17.30	Researcher	• Features are not on the same level
		External consultant	• Not all identified ideas are real features
		Product manager	• Create a selection of the features
22-2-2013	13:30-16:00	10 people present	WS3
25-2-2013	15:30-16:30	Researcher	• WS3 needs an extensive preparation phase
		External consultant	• There are multiple options to design the preparation and actual WS3
		Product manager	• WS4 is going to be changed into a “technology-push” workshop as a gap analysis
26-2-2013	13:00-15:00	10 people present	WS4
27-2-2013	15:00-17:00	Researcher	• Technology perspective is difficult for MV
		Product manager	• It might be more useful for AV and EF as these systems are more “open”
			• Preparation of cards for WS5
28-2-2013	11:00-14:00	11 participants present	WS5
7-3-2013	10:00-11:15	Researcher	• TRM evaluation
		Product manager	
7-3-2013	17:30-18:45	Researcher	• TRM evaluation
		External consultant	
8-3-2013	10:00-11:00	Researcher	• TRM evaluation
		Product manager MV	
12-3-2013	16:00-17:00	Researcher	• TRM evaluation
		Department leader PPM	
4-4-2013	15:00-15:45	Researcher	• Technology perspective is difficult for MV
		Leader strategic planning	• It might be more useful for AV and EF as these systems are more “open”
		Strategy portfolio manager	

Table 14: Log of meetings

9.5 Appendix E: Planning phase steps

Author	Gerdsri et al. (2010)	Phaal et al. (2003)	Cosner et al. (2007)
Initiation	Understanding the value of applying TRM in the organization	Define unit of analysis (scope and focus)	Demonstrate value early for support in organization
	Build awareness of why TRM implementation is needed	Articulate company objectives for process	Define scope, goals
	Discuss the detailed concept and the roll-out plan of TRM implementation		Appoint champion
	Raise urgency of why TRM implementation is necessary to all participators		
	Develop vision, objective, and scope of TRM implementation for the organization		
	Gain acceptance and sponsorship from top-management		
	Communicate vision for the buy-in and support from key players		
Development	Customize generic TRM process to fit with organizational setting	Identify information required to support the process	
	Prepare all participants to be ready to implement TRM process		
Integration	Form a working group responsible for activities related to TRM implementation	Appoint participants	Create roadmapping team
	Provide fundamental concept of TRM to all participants	Define required resources of workshop	
		Scheduling of workshops	