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INNOVATION ROADMAP FOR CUSTOMER VALUE-ORIENTED TECHNOLOGY FORECASTING: CASE CONCEPT TIRE

Master of Science thesis

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ABSTRACT

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There are many ways in which innovation can be sparked. Sometimes innovation can come from unforeseen events, coincidences and unexpected challenges, but most of the time, innovation is the result of hard, diligent and systematic work. However, the typical way to forecast technology forgets a critical element, the value a technology may bring to the customer. This is not a surprise, since technology is usually forecasted by experts who focus on their particular area of expertise, which is technology. Under these circumstances technology is forecasted for the sake of technology alone, resulting in cases of technology push, as opposed to what could be a more natural market pull.

The objective of this report is to challenge the common notion of technology forecasting by integrating inexperienced individuals with a view for customer perceived value, to an activity which is commonly carried out by experts, in a purely technological environment. The purpose of this approach is to complement the current existing literature of technology forecasting. To understand the implications of what such a model could imply, some of its features are analyzed through a case, the concept tire. This project was as a part of the Demola network. This project was done with a tire manufacturer, and it had the concrete purpose of using inexperienced individuals during technology explorations, which would later be implemented into the regular forecasting activities.

The final outcome of this thesis is a thorough new framework by the name of innovation roadmap. Nowadays all of the main processes of a company are customer-oriented and technology forecasting should be no different. The customer-first approach to technology forecasting may be able to give new insight that could bridge the forecasting gap between technology and customers. This study shows that customer-oriented technology exploration performed by inexperienced individuals can be effective and yield truly valuable results.

PREFACE

I have always had a latent interest in future technologies and technology exploration. In the course of my first Demola project, this passion developed further as I became an active agent in a project of technology forecasting. Although perhaps unorthodox compared to how technology forecasting is typically carried out, this experience left a big impression on me. Once the Demola project came to an end, I decided this would be a fascinating topic for my Master thesis.

The writing process of this thesis was interrupted during my work as an intern at the Finnish Ministry of Education and Culture. The added hours of the long commute between Tampere and Helsinki amounted to long work days and the writing process became stagnant. After my 3 month internship was over, I was able to return to my Master thesis with a new focus in mind. The time away from this report gave me a different outlook on things which proved most valuable.

Firstly I would like to thank the project partner representative from the case company. His guidance was key in steering our project into success. Secondly, I would like to thank Dr. Jouni Lyly-Yrjänäinen for his help during my studies. His teachings during the courses of Academic Writing 1 & 2 gave me the necessary tools to be able to approach the process of writing a Master thesis with confidence and independence. Similarly, without his guidance, the writing of this thesis would not have been possible. In the same fashion, I would like to thank Professor Petri Suomala for his help during the writing of this thesis. Finally and most importantly, I would like to thank my wife Sanna Berlanga for her endless support during my studies. Her encouragement and understanding was paramount and without her I would not have been able to complete my Master degree.

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LIST OF SYMBOLS AND ABBREVIATIONS

B2B	Business to business
NPT	Non-pneumatic tire
TCO	Total cost of ownership
TF	Technology forecasting
TFSC	Technological forecasting and social change (Journal)
TPMS	Tire pressure monitoring system
R&D	Research and development

1. INTRODUCTION

1.1 Background

In the business world of today, some companies stay ahead through cutting edge innovation. These are firms that try to differentiate themselves by setting trends, unveiling never-before-seen products or services and being trailblazers. At the core of such corporations there is a great deal of R&D, a systematic approach to change, and brave attempts of predicting future tendencies and needs. Other firms, on the contrary, take a different approach. Some prefer to be followers, to enter the game once it has been proven to work. Such companies may choose to wait for other firms to take the initial steps of perfecting an innovation and educating the users on how and why the product at hand should be purchased, sparing themselves from the painful process of being the first in the market, but entering the market at the precise time when there is still time to obtain sufficient market share. This thesis focuses on the first kind, the innovator.

Technology forecasting (TF) can be defined as the assessment of characteristics of future machines (Martino, 1993). TF may be seen under a variety of labels, such as “Competitive technological intelligence”, “technology foresight” or “foresight” (Porter 1999). Porter et al. (2011) also mention how the terms “impact assessment” and “risk assessment” in technological context can refer to TF.

Most, if not all, of the literature available on technology forecasting, centers on the fact the experts are at the very core of TF-related activities. Through whichever method a technology is being forecasted, a group of professionals with vast knowledge on the matter under examination is a mandatory component. This thesis challenges this notion, hence complementing TF studies.

One of the fundamental arguments of this report is innovation efforts which are driven by a group of individuals with no expertise and lacking proficiency on the topic of development. The belief behind it is that experts may often find it hard to “think outside of the box”. Their experience limits them from thinking beyond what is plausible and it closes a world of opportunities.

Miller (1982) defines tunnel vision a form of selective attention which contributes to inadequate problem formulation and partial solutions. Experts may sometimes think narrowly because they are quick to dismiss concepts on the basis of them not being possible technology wise. Sometimes forecasting a new and complex technology can be problematic due to the large amount of unknowns; forecasts under such conditions could be rendered inaccurate (Wheeler & Shelley 2010). It would then seem that specialists do not always have the correct answer. This opens the door to the premise of forecasts through inexperienced individuals.

Regardless of the strategy the firm decides to follow, there is the clear need to have the ability to know what customers really need and how to offer it to them. Gummesson (1993) indeed comments how business live off their customers and, thus, they have to know what customers are willing to pay, and they must also know how to persuade them to buy their product. The firm needs to be able to identify the attributes of its offering which are vital to the buyer and tailor its product around them in order to guarantee that it will provide the benefits that are expected upon purchase and usage. In other words, the company needs to know how to offer value to its customers.

It is precisely value which becomes essential to the purpose of this thesis, more specifically the adaptation of customer value to technology forecasting. There is not much literature available on customer value in future innovations, though one author scratches the surface. Möller (2006) asserts that the creation of radically future-oriented value (based on technological related innovations) seems to involve multi-actor development networks. This would require complex networking capabilities in order to commercialize a targeted new innovative offering. (Möller 2006). Though value in innovations is acknowledged by the author, there is not much to go on. This brings forth the need to evaluate some of the existing literature available on customer value and find elements which could be of use in the case of innovations that are only in conceptual stages.

1.2 Objective

This thesis introduces a new approach to technology forecasting called innovation roadmap as a way to generate new leads in the continuous process of innovation. The present report has two founding literature dimensions, technology forecasting and customer value. It is fundamental to extensively research and become acquainted with both concepts in order to identify and understand the gap that could be filled by the concept of value-centered innovation roadmap. Most importantly, it is crucial to understand both concepts well in order to find common elements that can bridge the two of them together in a logical manner.

It is unarguably clear that inexperienced individuals cannot outperform experts with years of experience and thousands of hours of in-field involvement. Whether in technology forecast, in research of a specific technology or any other similar activity unexperienced individuals will most likely never do comparable work to that of experts.

This thesis does not look to disprove what has been done for decades and what will most likely continue to be the standard way to operate for the foreseeable future. On the contrary, this report looks at the opportunity of including inexperienced persons in technology forecasting and innovation related tasks, though receive some level of guidance and assistance from experts in the area. The purpose of such alternative is to function as a way to spark innovation; to give fresh, out-of-the box and unprecedented (though admittedly perhaps unfeasible at times) ideas to specialists who can at times be blinded by their own expertise.

Similarly, these experts typically involved in TF tend to be engineering professionals whose sole focus is the development of the technology itself, without often questioning how a potential new technology and its application can bring value to customers who are not aware of it yet. The aim of this thesis is to provide an additional tool to technology forecasting, by challenging the notion that only experts should be involved in such studies where technology as a standalone is the solution. Therefore the objective of this thesis is…

> *... to introduce the idea of innovation roadmap, a spin to technology forecasting which is executed by actors with no expertise and limited knowledge on the area under scrutiny while considering customer value from early stages in order to complement the technology forecasting process and help find potential innovations which could otherwise go unnoticed.*

To address this objective this thesis goes through technology forecasting and customer value. Technology forecasting is explained and the need for customer value is identified. After this, customer value is analyzed and adapted to suit the realm of forecasting. A framework is then designed to demonstrate the significance of early onset customer value elements to atypical efforts of innovation development. In addition, this thesis is based on a project work conducted with a project partner executed through the innovation platform Demola Tampere.

1.3 Research method

Although research is important in both business and academia, there is no consensus as to how it should be defined. One reason being that research may hold a different meanings to different people. However, with regards to many different definitions, there appears to be an agreement that research is a process of enquiry and investigation, it is systematic and methodical and it increases knowledge (Aramatunga el al. 2002). Gummesson (1993) indicates that the general reason for doing case study research is to better understand complex phenomena. From the simplest point of view, research can be theoretical or empirical.

Theories are formulated to explain, predict and understand phenomena and to challenge and extend existing knowledge. Parting from this, theoretical research investigates theories so as to enable a new theoretical framework, which explains the research problem under study.

Empirical research is knowledge derived from investigation, observation, experimentation or experience. Empirical research is made of gathering and analyzing existing (empirical) data and reporting findings and conclusions (Minor et al. 1994). As can be inferred, theoretical and empirical research are opposites. Theoretical research resides in books and other written material, while empirical thrives on action and its documentation. These are nonetheless opposites that complement one another.

There are two fundamental schools of thought for research, logical positivism and interpretative science. Based on these two schools research may be categorized into two distinct types: quantitative and qualitative respectively. The quantitative approach comes from a strong academic tradition that places trust in numbers that represent opinion or concepts, while qualitative concentrates on words and observations to express reality. (Aramatunga et al. 2002)

Research rarely depends purely on one kind of method. Gummesson (1993) clarifies this by saying case studies benefit greatly from a combination of the two. Furthermore, he further states that there are five ways to gather empirical data, they are:

- Existing material
- Questionnaire surveys
- Qualitative interviews
- Observation
- Action Science

The first method, existing material, consists of utilizing any previously published material. It is also referred as secondary data, as they were initially created for somebody else’s purpose. Second, questionnaire surveys are sets of standardized questions aimed at obtaining information from an array of sources. These questions can be qualitative as well as quantitative and are usually carried out with interview guides that include the topics to be covered. Third, qualitative interviews are the most common case of generation data in a case study; they are more informal and similar to a conversation rather than a series of questions and answers. In a qualitative interview the questions are not necessarily in a pre-established order and they tend to be open ended. Observation consists of a watching the events directly all senses and even intuition, in order to detect stimuli that may not be perceived by others. (Gummesson 1993)

Though these four previous research methods range from the partly theoretical to the empirical and vary in degree of involvement, they all have something in common; the researcher does not interfere with the organization under study. In other words, the researcher is a spectator who may have some degree of interaction with the organization, but will never have any direct input in the actions of the company. The fifth and last method is action research and it is the most demanding of all. Gummesson (1993) describes it as the direct involvement of the researcher in the process; the researcher no longer just observes and reports, but rather has a hands on approach. The result is obvious, the process under research has a different result that it ever would have had. In other words, the actions of the company affect the research just as much as the researcher affects the current and perhaps even near future actions of the company.

The case analyzed in this thesis is a combination of existing material, qualitative interviews, observation and action science. It should be made clear that action science was executed to a very limited degree. Existing material was one of the main sources during the study, as it was needed for the actors of the project in order to become better acquainted with the tire and the industry, but most importantly to read on other technologies. Observation was limited to a one-time factory visit to understand the process of making tires and identify opportunities for future innovation. Qualitative interview took place in the way of scheduled sessions between the members of the team project and the project partner. Finally, action science is manifested in how the efforts of the team had an impact in the work of the researchers and engineers at the case company. This impact could have been as simple as giving the experts a new way to look for innovations or as elaborate as providing them a concept which they could attempt to bring to life. Naturally, if the project was successful, this impact would be bigger. This aspect is further explained in Chapter 5. The way in which these three methods of data gathering interacted in the project are represented in Figure 1.

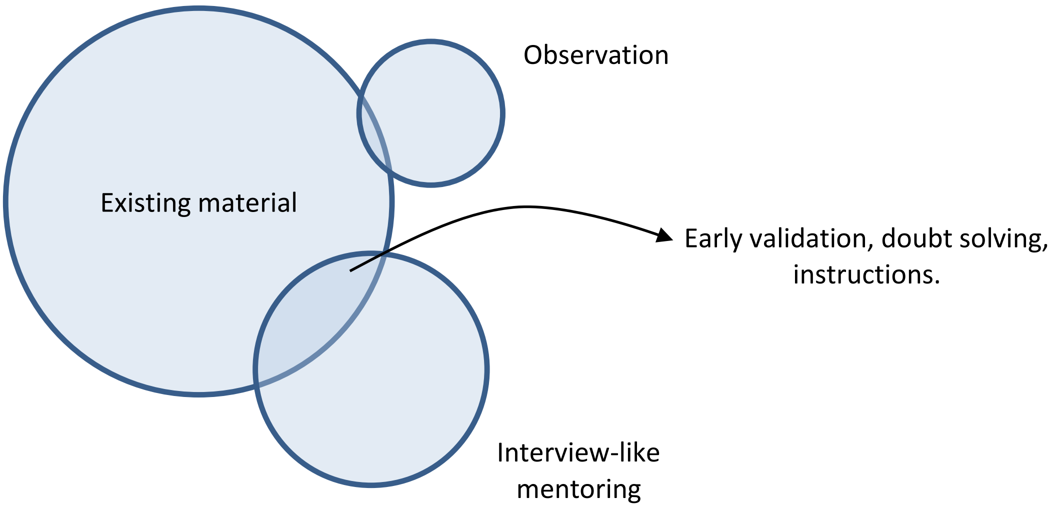

Figure 1. *The research methods at the early stages of the project.*

1.4 Research process

The research process officially kicked off in late September 2014 through the kick-off event of Demola. This event is an official welcome to all members of different projects, a formality of the Demola process and an introduction to the inner workings of the innovation platform. The case extended from September 2014 until the end of January 2015. At the end of the case, the project partner had a period of one month to make a decision on whether it would accept or reject the project results. More details on the specifics of the project and important milestones will be detailed in the following section.

During March 2015, the author of this document negotiated the possibility of a thesis position with the project company. Although the position was not possible at the time, the permission to write this thesis was given by the case company under the condition that no sensitive information was revealed. Not only is no information from the company revealed, but only minor details from the results of the case are depicted in this report.

The motive for the previous is that the project members prefer for this information to remain closed, both for their interest and the interest of the project partner. The results hereinafter described allow the understanding of the results and their relation to the built framework. The literature review and writing of this thesis took place from May to August of 2015 and then from February to April of 2016. All of the information depicted in this section is put into a timeline in Figure 2.

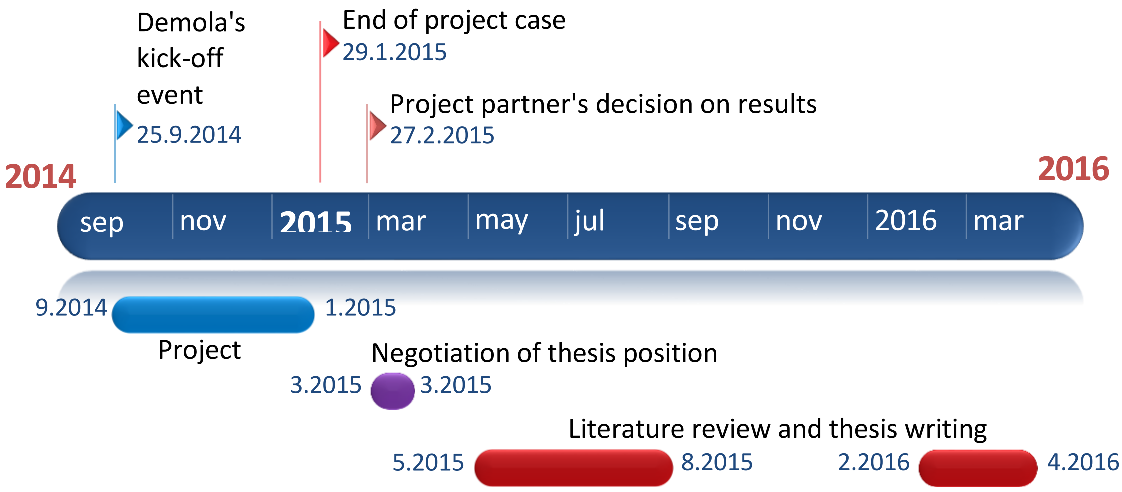

Figure 2. *Timeline of the research process and development of this thesis*

It was not until the end of the project that the author of this report saw the opportunity of a thesis related to the case. A few weeks after the response from the project partner the author decided to push ahead with the thesis. During the case there were other relevant milestones, both from Demola as from the case itself, but this will be discussed later on.

1.5 The main actors in the case

The case was done in Tampere as a part of the Demola network. The project had three main actors, which were:

- The project partner (case company)
- Demola
- The project team

The project partner assigned one of its development engineers as a liaison. During the entire duration of the project he was the only representative from the company directly involved in the activities. He acted as an advisor to the project team members and at the same time provided guidance on matters that should be further continued or brought to a halt, according to the interests and needs of the company. On behalf of Demola, a facilitator was assigned to the case. His role was to ensure that the desired objectives of the project partner were fulfilled and to make sure important milestones were achieved, while following the Demola way of work

1.6 Demola

Demola is an innovation ecosystem, an international organization that facilitates co-creation projects between university students and companies (Demola, Online). The purpose of Demola is to create innovative solutions to all kinds of needs. It gives students the opportunity to take part in real projects and get hands-on experience, to apply the teachings of school in real world applications, to do some networking and even receive credit points. It allows companies to have a fresh take on an existing problem, whether it is business, technology or any other discipline. It allows firms to transform ideas into validated concepts and prototypes and gives them the opportunity to tackle a challenge from a different point of view. Finally, it enables higher education institutions to create university-business collaboration, applying theory into practice and at times even giving them the chance to conduct new research.

When it comes to the development of the project, Demola is the steering force behind it. It provides the framework and the guidelines on how projects are done. Through experience and constant learning, Demola has developed a process that is formatted and facilitated. It is a process which is systematic and runs on schedule. This is done as to guarantee work is as creative as possible, yet work is kept under control both in terms of time and deliverables. Demola provides a framework that makes it easy for partners to cooperate. Each partner has a clear role with work which is guided by simple procedures. Contracts, which among other things, detail intellectual property rights and licensing models are provided by the Tampere-based innovation platform.

The project partner specifies and delimits the expected outcomes for the project, and Demola provides the tools necessary to achieve those outcomes. The team is given the liberty to operate as they best see fit, taking the project in the direction they prefer as long as it stays loyal to the expected outcome. Demola provides the criteria that define a successful project but it has no opinion on this decision, that responsibility relies entirely on the project partner alone. At the conclusion of the project, the company makes a decision on the project outcomes. If the company is not satisfied with the results, then it can simply walk away. Contrarily, if the project partner is convinced by what the project team has achieved and would like to keep the results, e.g. to utilize them or develop them further, then it has the option to license said results. The license is paid according to the level of satisfaction of the case company. As mentioned, the criteria is established by Demola, and it can be seen in Table 1.

Table 1. *Demola criteria for licensing and its levels.*

Level	Criteria
1	Project done as planned. Good quality implementation and working demonstrations according to project description and plan.
2	Criteria 1 significantly exceeded. Overall implementation has very high quality and there are some highly interesting new ideas to improve the concept, implementation, user experience or business potential.
3	Exceptional result, e.g. novel concept ideas with clear business value with very high quality implementation and demonstration delivering a user experience wow!

Licensing the results means the company is able to use them to discretion, albeit it is not the sole owner. In compliance with Demola stipulations, the team members remain as co-owners of their results, even in the event of licensing. This means that regardless of the intentions of the project partner with the results, the team members are free to make use of the results as well, for instance, if they were to pursue a venture of their own.

1.7 Structure of this thesis

This thesis is logically divided into seven chapters. The content of each chapter is the following:

1. Chapter 1 introduces the background and the main objective of this work. It also details the research methods used as well as describes the research process, its time frame as well as activities related to literature review and thesis writing. Similarly, the Demola network is described.

2. Chapter 2 reviews the first dimension of literature employed for this study, technology forecasting. The concept is defined and its importance in the business world is established. A brief history of significant events is told and the most noteworthy stakeholders of the TF process are listed. Different types of forecasting and specific methods are discussed and finally some limitations are mentioned.

3. Chapter 3 analyzes customer value, the other literature dimension of this work. The concept of customer value is thoroughly defined and its need is expressed. Ways to measure it are discussed from the perspectives of the customer and the company, and customer value assessment is introduced. Finally the concepts are translated into terms which are suitable for technology forecasting.

4. Chapter 4 discusses the tire and the tire industry. Firstly, a brief history of the invention of the tire is given. This is followed by a description of the tire, after which the winter tire is introduced and relevant differences are pointed out. A representation of the winter tire industry is performed and notable innovations in the tire are discussed.

5. Chapter 5 discusses the project. The need behind the project and its expected outcomes are described. Relevant details of the case are discussed carefully and its final results are depicted and some relation to the literature review is already made.

6. Chapter 6 presents the framework of this thesis. The literature review and the company case come together in order to concretely form the new innovation roadmap framework, which moves away from a technological point of view into a customer value centered perspective.

7. Chapter 7 concludes this report. Final findings are presented and limitations are pointed out.

2. TECHNOLOGY FORECASTING

2.1 Defining technology forecasting and its importance

In the corporate world, competitiveness is key to stay afloat. According to Brownlie (1992), survival depends on how well a firm adapts its capabilities to a constantly changing environment. He also establishes that companies with long-term success move towards technology and particularly emphasizes how activities relating to forecasting of technological change should be embedded into the long term strategy of the firm.

On the other hand, Mishra et al. (2002) highlight how nowadays the rate of change of technology has increased, which consequently shrinks product lifecycle. Under such tempestuous environment companies have to continuously upgrade their technologies through systematic forecasts. Mitchell (1992) complements this by saying how this technology change rate makes the need for long term planning greater in the new industries, shown in Figure 3. Sometimes there is a need of an industry view, not just a company view, making forecasting altogether more indispensable.

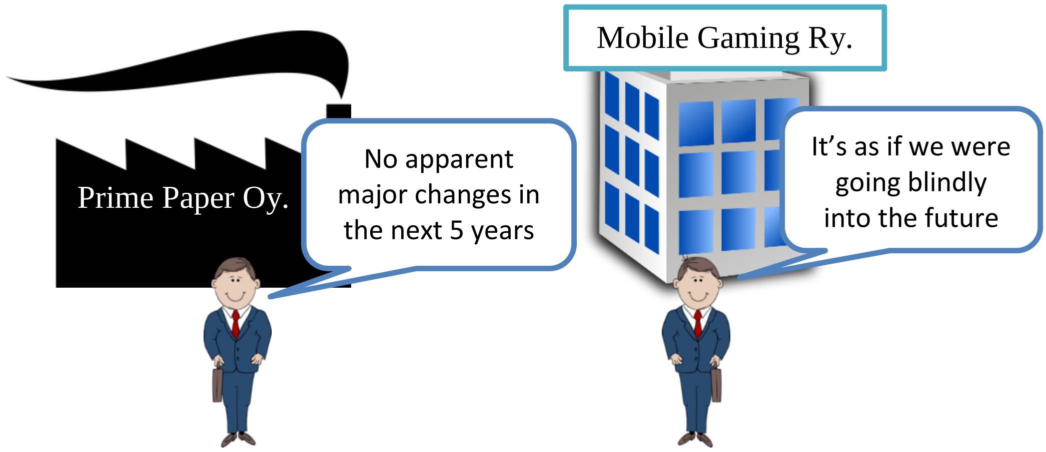

Figure 3. *The urge to forecast may differ between industries.*

Technology forecasting (TF) is a common need, but before moving forth a common definition should be established. One could on its own deduce the meaning of technology forecasting. Forecasting being the analysis of past trends and tendencies in order to speculate what the future will look like. In the particular case of TF, this is applied to technology.

In the simplest sense, technological forecast is the estimation of future characteristics of useful machines, procedures or techniques (Martino 1993). It is worth noticing the word "procedure"; when dealing with technology, the immediate association is to think of machines, gadgets and physical elements. There is more to technology than just the palpable. Martino (1993) clearly states how technology is not limited to hardware, it also includes software and know-how, which is shown in Figure 4.

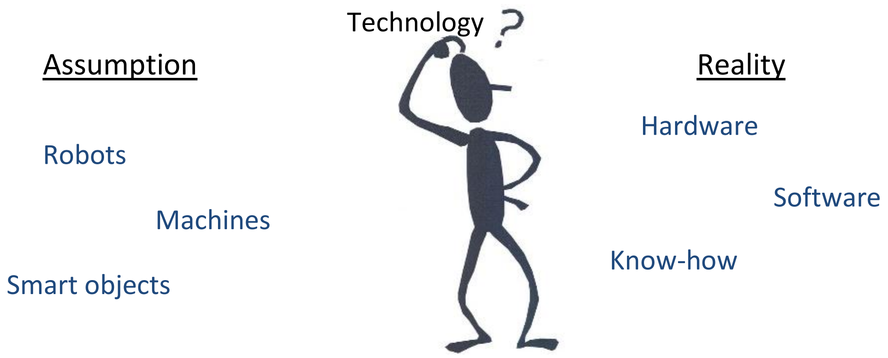

Figure 4. *Technology is a much broader term than just hardware.*

Mishra et al. (2002) make an important remark; forecasting can address either incremental changes of current technologies or long-run changes of emerging technologies. That is to say, performed at the proper time, forecasting could have estimated the future performance of gasoline and diesel motor vehicles, or it could have assessed the rise in importance of electric vehicles.

One could think forecasting technology is not necessary. According to Martino (1993) there is no choice between forecasting and not forecasting. He further asserts that any individual, organization or nation that can be affected by technological changes participates in forecasting with every decision that allocates resources to specific purposes, even unknowingly and perhaps in a rather sloppy manner, firms engage in TF. This is shown in Figure 5.

Figure 5. *TF is used for much more than just guessing how crazy the future will be.*

In other words, TF is not a luxury, but a common necessity which firms must perform, whether formally or informally. When a firm decides what their next year R&D budget will be, when a research center decides how many researchers it will employ or when a firm estimates how many users its newest innovation will obtain, they are forecasting the future. It would seem then that companies engage in informal TF on a nearly daily basis.

It is clear that systematic, methodic TF cannot be performed daily. However, some level of formal TF is important to a firm because it will be the basis for future decisions. This way, even "informal" forecasting decisions will have been taken with some measure. Martino recognizes nonetheless particular reasons why institution make forecasts, shown in Table 2.

Table 2. *Reasons for technological forecasting (Adapted from Martino 1993).*

To maximize gain from events that are the result of actions taken by the organization	Active
To forecast demand for purposes of production and/or inventory control	
To forecast demand for facilities and for capital planning	
To forecast demand to assure adequate staffing	
To develop administrative plans and policy internal to an organization	
To develop policies that apply to people who are not part of an organization	
To maximize gain from events external to the organization	Reactive
To minimize loss associated with uncontrollable events external to the organization	
To offset the actions of competitive or hostile organizations	

The table is split into two categories. Reasons that have to do with the company anticipating the competition and actions that are a responsive. The latter could seem as a passive response to events that would otherwise be unanticipated and threatening.

Technological forecasts calculate the invention, timing, characteristics, dimensions, performance and even rate of diffusion of a device or process (Fye et al. 2013). When used correctly, forecasts can help users anticipate competitors and avoid a technological surprise.

For any given company, strategic planning is a basic function, though TF is often left out. Brownlie (1992) mentions how the integration of the R&D functions is essential to achieve long-term corporate objectives. However, integration R&D "as is" is not the solution. It takes a solid understanding of the use of TF to strengthen the link between R&D and business planning. Furthermore, TF can be seen as a vehicle to share information within the company.

The statements of Fye and Brownlie fall under the passive and active category respectively. Based on these statements it can be understood that there is no right or wrong reason for a company to decide the motive behind their TF efforts.

While authors such as Lin et al. (2010) as well as Porter & Watts (1997) simply attest that TF is employed for decision making, other authors build up on this concept. TF is not only used to gamble on what the future will look like and create a product which matches such given criteria. According to Bouwman & van der Duin (2010), TF can be used in many cases, ranging from vision development on the future to investment decisions regarding emerging technologies and how these technologies influence and even substitute one another. These authors also mention that TF is often used at the initial stages of any innovation process, when the decision makers and other corresponding parties want to know possible trends in the years to come.

The biggest payoff of TF is not the technology itself, but the applications of this new technology, which requires understating of organizational, market and social factors (Coates et al. 2001). It is crucial to understand this concept; TF for the sake of technology alone will lead nowhere and will render efforts useless. Coates et al. (2001) affirm how nowadays both government and industry alike have turned their attention to the market exploitation component rather than the invention component alone.

2.2 A brief history of technological forecasting

It is difficult to simply pinpoint the birth of TF, especially since any related activities could have had a different name throughout history. Figure 6 shows some events of historical significance in TF.

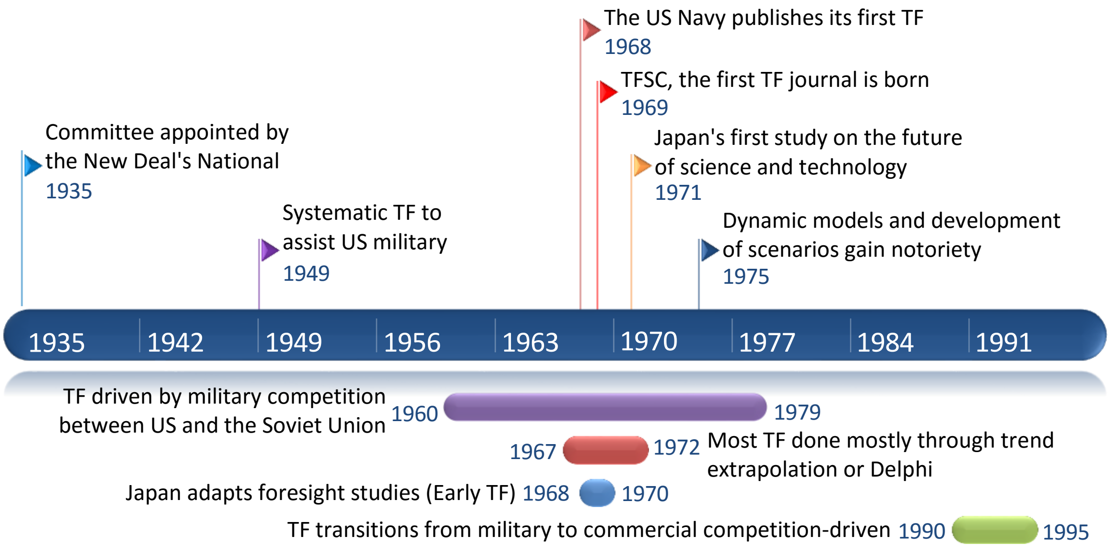

Figure 6. *A timeline of important TF events.*

The image does not depict an extensive list of events, rather some important historical milestones. It is worth recognizing that TF was not a discipline born through consensus, but rather from the need to predict the future and gain advantage in a world that was becoming globally competitive. Later on TF became a more standardized practice.

According to Coates et al. (2001), the first official record of a systematic outlook on the future of science and technology dates back to 1935 when the New Deal's National Resource Commission tasked a committee to look into the future 13 major inventions. The intent of the resulting report was to predict the economic and social impact these emerging technologies would have.

By 1949, sponsored by the US government, the development of TF in a more systematic manner was a reality, mainly to aid military strategists (Coates et al. 2001). Military competition with the Soviet Union drove TF during the 60s and 70s (Porter 1999). The Cold War saw technological advancement in the form of guided missiles, nuclear weapons and computing (Coates el al. 2001). Linstone (1999) emphasizes how the rise of TF driven by the cold war was a marriage between the military, industrial and academic sectors in the US, motivated mainly by the then newly created US Airforce. In fact, According to Cetron (1969), it was during 1968 when the US Navy published its first technological forecast. It is no secret that war has always been a driver for technology and innovation.

At the same time, Japan began looking into TF on its own. Kuwahara (1999) specifies how Japan was a late starter in the development of Science and Technology but was nonetheless hugely successful. There are several contributing factors. First there was the adaptation of foresight studies during the late 60s. Second and perhaps most important was how in 1971, through the Science and Technology Agency (TSA), Japan started conducting a large study on the future of science and technology. The aim of this study was, among other reasons, to identify areas of strategic research and generic technology that could yield the greatest economic and social benefits. These studies were performed on a lustrum basis all the way to 1997, each study projecting 30 years into the future. (Kuwahara 1999). It is clear that in great measure the success of the efforts of the Asian country could be attributed to the nationwide integration and the constant and systematic approach of its efforts.

During the late 60s and early 70s, most technological forecasting was done either through trend extrapolation or Delphi (to be defined later). By 1975, while the previous two were still widely used, dynamic models and development of scenarios (desired or alternative futures) were beginning to gain notoriety. (Martino 1980) Different forecasting methods will be described in Section 2.5 in more detail.

After the peak of military driven TF there was a change. The 90s saw a transition in innovation; military development was supplanted by commercial technological competition as the main motivator for TF (Porter 1999). This could be seen as a result of a reduced need of active military actions and increased commercial competition powered by globalization.

All the efforts in TF brought forth the need of a publication to go along with them. Linstone (1999) relates how a technological forecasting workshop, which took place in New York in 1968 saw the conception of the first journal in the matter. In 1969, the journal "Technological Forecasting and Social Change" was born. Issued by Elsevier publishing, it is a well-respected reproduction that continues to exist to present day.

2.3 Actors and other stakeholders

So far the basics of TF and the need behind it have been comprehensively discussed. This section discusses the different parties involved when undergoing TF. Within a firm, TF tends to fall on individuals closely linked to research and innovation. Other times, forecasting activities could be outsourced to consultants.

It would be an error to believe forecasters alone are responsible for all decisions regarding the TF process as a whole. An error that is not uncommon is for top management to avoid getting involved in technological decisions and leave them to R&D specialists (Brownlie 1992; Coates et al. 2001; Porter & Watts 1997). This is an error which should be avoided (Figure 7). In regards to technology planning, top management should define the corporate goals, which in time defines the scope and timing of the technological needs and R&D efforts of the firm. In regards to TF in particular, it is the responsibility of top management to be actively present in every step along the way (Brownlie 1992).

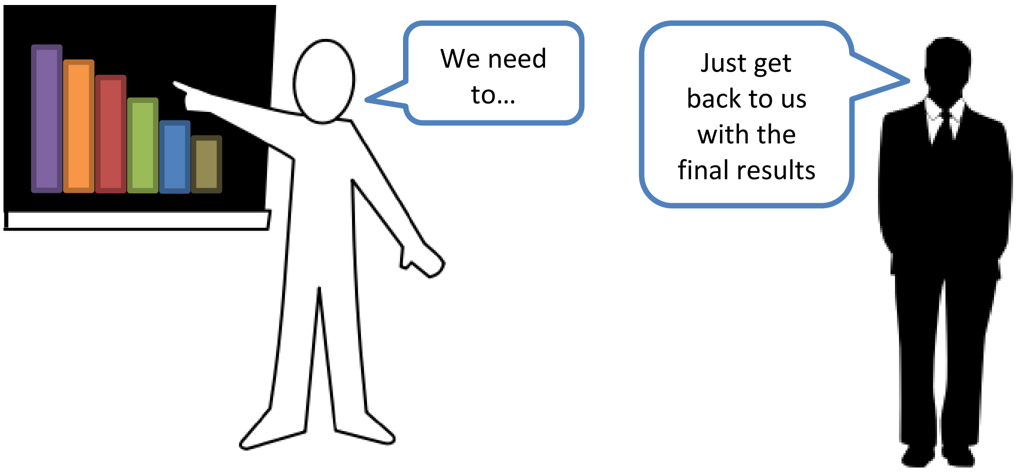

Figure 7. *The lack of integration of top management in TF is a major mistake.*

Coates et al. (2001) discuss how TF has been and will continue to be shaped by the needs of corporations and government agencies, however, it will also depend on the views of the public about technological progress, economic competition and the role of the government.

Poor communication between marketing and R&D are barriers to the success of any industrial innovation; in fact, the lack of integration of R&D management with all other areas of a firm is a major weakness (Brownlie 1992). Needless to say, this issue is directly transferable to medium and long-term innovation efforts which include TF. Coates et al. (2001) reinforce this notion by stating that TF platforms are becoming more integrated with company functions and policy setting.

TF is not only important for the company looking to attain a competitive edge over others. Bouwman & van der Duin (2003) asseverate that research into new technologies and the way they may be accepted and used is incumbent to the whole specific industry, policy makers (such as the government) and end users. This can be easily exemplified. Research into a tire with the potential to drastically decrease road resistance selectively, thus reducing fuel consumption, would have the potential to affect all the aforementioned stakeholders. Other companies would conduct similar research to avoid falling behind in the game. The government could in turn use said product in order to change the policies on CO_2 emissions. Finally, environmentally-minded car owners could make this new product their primary choice. This is shown in Figure 8.

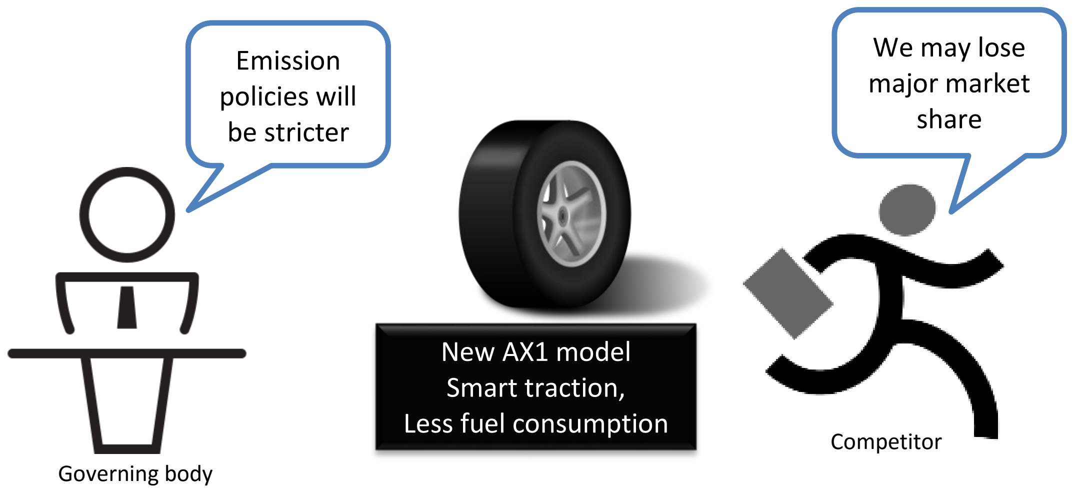

Figure 8. *How a new technology/innovation can affect different stakeholders.*

It has been highlighted how important the integration of top management is when it comes to participating in TF activities. Coates et al. (2001) agree with this statement, and they take it a step further, by saying customers should be urged to participate in TF activities as well.

When talking about stakeholders and integration, Japan took the concept of TF to the macro level. As Kuwahara (1999) affirms, during the 60s and 70s governmental R&D projects were implemented through the coordination of several governing bodies. The Ministry of Education allocated budget for basic research in universities and colleges. Meanwhile other ministries such as International Trade and Industry, Health and Welfare as well as Post and Communications had their own research budgets and administrative goals. It all came together with the help of the Science and Technology Agency which undertook strategic research to bridge all research efforts. (Kuwahara 1999) While Kuwahara makes no formal mention of TF, its characteristics can be appreciated, meaning the systematic encompassing efforts in an attempt to predict future technologies and its applications. This section has discussed common actors and stakeholders in TF activities. Figure 9 illustrates them according to the order of importance.

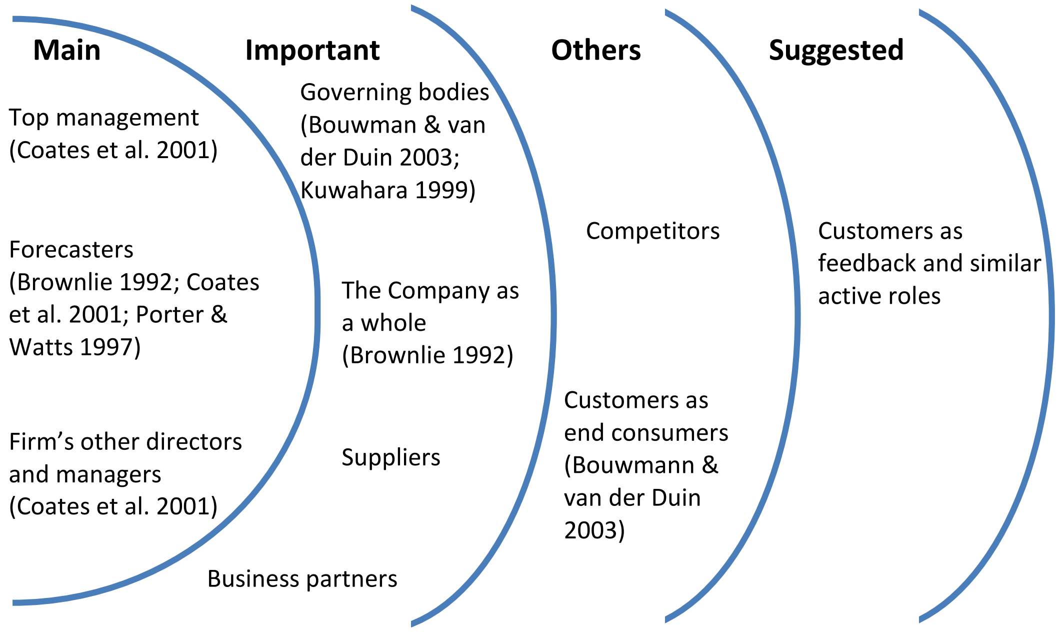

Figure 9. *Common stakeholders in TF activities and their degree of involvement*

The image describes stakeholders commonly involved in TF activities, in any case, this list may be more extensive in particular occasions. These are stakeholders identified during the literature review for this report, others are inferred by the author of this thesis. For practical purposes, only central stakeholders to the TF process are considered. When embarking on a new business or technology venture, such as TF, the number of total stakeholders could round the tens or even hundreds.

2.4 Elements and types of forecasting

Innovation easily comes to mind when discussing TF, which is why it is worth analyzing. According to Coates et al. (2001), innovation has two main components: invention and market exploitation. Seen from a different perspective, an invention does not become an innovation until it has been widely adopted by the market.

Coates et al. (2001) further state how in the 70s the main driver of TF was predicting the future characteristics of machines, procedures and techniques and were measured by whether or not they became true. As mentioned in Section 2.1, the true benefit of TF is not technology per se, but its applications.

Martino (1993) argues that a technological forecast, as any other forecast, has four elements:

- The technology being forecasted
- The time of the forecast
- A statement of the characteristics of the technology
- A statement of the probability associated with the forecast

In general, forecasting methods can be sorted into two types: quantitative or qualitative. Quantitative, as its name implies, are methods that consist of numbers, more specifically, the mathematical and statistical analysis of numbers, tendencies or any distinguishable patterns. Qualitative, its counterpart, rely on knowledge, expertise, intuition and even feeling. Lemos & Porto (1998) depict them in a poetic instance, paralleling qualitative and quantitative methods to art and science respectively: The hot and idealistic against the cold and measured. This is portrayed in Figure 10.

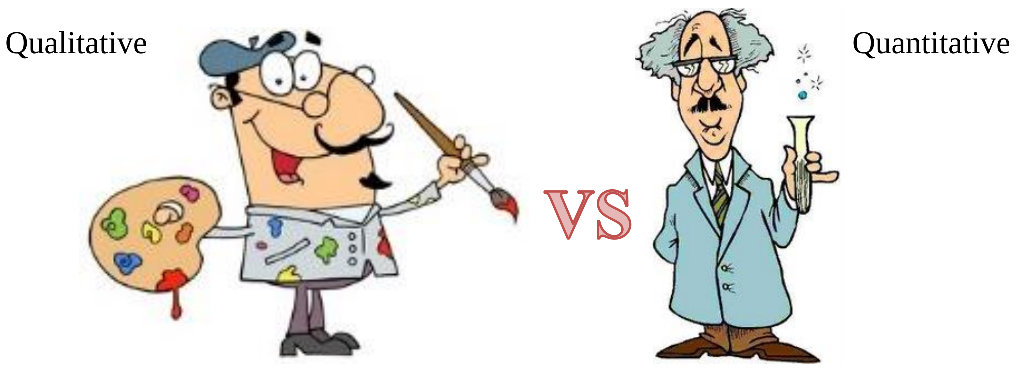

Figure 10. *Qualitative and quantitative methods ("art vs science") are opposites that complement each other (Lemos & Porto 1998).*

Though these two methods could be seen as rivals, they are complementary to each other. According to Fye et al. (2013) experts, i.e. qualitative methods, are best at predicting if an event will happen. Quantitative methods on the other hand, are most accurate at predicting when, though in general, quantitative methods tend to be more accurate. It is for this reason that technology forecasters often use a combination of different methods in the search of more accurate results. Analyzed from a simple perspective, a forecaster cannot "put all his eggs in one basket", forecasting as such is a discipline bound to inexactitudes.

Even when perfectly performed, a forecast can be largely inaccurate. Performing more than one study at once can either strengthen the results, or provide new insight to weigh during decision making. Anderson et al. (2008) reaffirm this statement and suggest that, when undertaking the tricky task that is forecasting, one should not stick to one single method, rather dare and perform multiple methods and combine the results. This would help in reducing errors arising from faulty assumptions, biases, or mistakes in the data. It might be hard to believe, but forecaster biases and assumptions can have a large negative effect on the final results. This and other weaknesses of forecasting will be discussed in Section 2.6.

Ironically enough, as reported by Fye et al. (2013), quantitative forecasts that use complex methods are less accurate than those that use simple methods. This assertion is based on a study of 201 forecasts. While the results of this study should not be followed blindly, they certainly provide food for thought with a substantial basis.

Based on all the previous it can be claimed that forecasting can be a trial and error process. After all, experts are made during such process. Sometimes choosing between qualitative or quantitative methods can be a complex task.

A forecaster may have certain preference or preconceived ideas as to the type of forecasting he or she would like to use. It is true that often either type of method is acceptable. Nevertheless, there are guidelines regarding when qualitative methods could be chosen as the starting point.

On the word of Martino (1993), there are three conditions when expert opinion, i.e. qualitative methods, is always needed. First, when no historical data exists. The second condition is when there are external factors which are more important than the factors which governed the previous development of the technology. An example of this was the intention of Kennedy to make the moon an objective in space technology. Finally, another condition which make qualitative methods necessary is when the development of the technology depends on moral and ethical considerations over economic and technical ones. An example of this would be research on fetal tissue obtained via abortion. (Martino 1993) These guidelines are shown in Figure 11.

Qualitative	Quantitative
• No historical data available. • Important external factors. • Ethical considerations involved.	• Plentiful historical data available. • No major external factors. • No ethical factors of any kind.

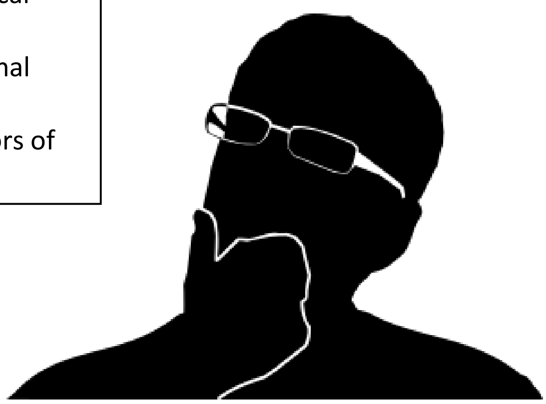

Figure 11. *Guidelines for choosing qualitative or quantitative methods as the starting point.*

The lack or unavailability of statistical samples can be decisive when choosing between qualitative and quantitative. It goes without saying that experts in the technology at hand are a requirement for any qualitative analyses. This is somewhat logical, in order to speculate what the future holds, the individuals discussing the matter at hand must be well informed on what the past of said technology looks like, as well as what is there available now and what is the focus of the industry in present time.

Technology forecasting is not an exact science; there is no right or wrong way to do things. There are guidelines and instructions which set a starting point, but ultimately it is up for the company to collect its best practices along the way and learn from its mistakes in order to improve and perfect their own forecasting abilities.

One more classification which is worth looking into is normative and exploratory technological forecasting. In reality, rather than a classification, these are approaches to forecasting. According to Cetron & Ralph (1971), in exploratory forecasting technological parameters and functional capabilities are projected into the future, starting from a base of accumulated knowledge. In normative forecasting, future goals and missions are identified and evaluated technology wise, the process is then worked backwards to the present in order to identify technological barriers and deficiencies. (Cetron & Ralph 1971) These different approaches can be seen in Figure 12.

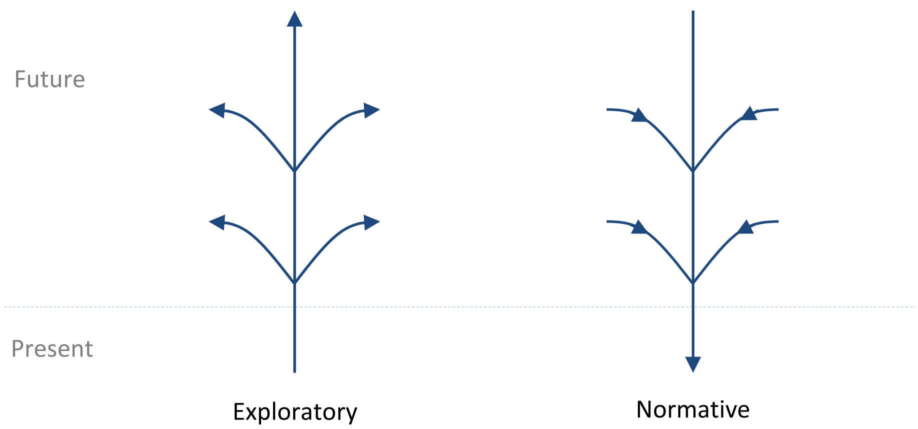

Figure 12. *Exploratory and normative TF (Adapted from Jantsch 1967).*

According to Jantsch (1967) there is a fundamental polarity between exploratory and normative TF, one is action while the other is reaction. Exploratory forecasting is opportunity-oriented, while normative forecasting is mission-oriented. (Jantsch 1967) This is true in a way, normative forecasting could be seen as a form of anticipated reaction.

Simply put, exploratory forecast is used to estimate what future technologies will look like, normative on the other hand is used to identify technological barriers. It is perhaps for this reason that most TF is done through exploratory approaches, while normative approaches tend to be used for policy making (Cetron 1969). The most important thing to know is that exploratory and normative are just different approaches to forecasting. Both can be done either through quantitative or qualitative methods.

However, it is argued that the full potential of technological forecasting is realized only when exploratory and normative components are joined iteratively (Cetron 1969; Jantsch 1967). This is illustrated in Figure 13.

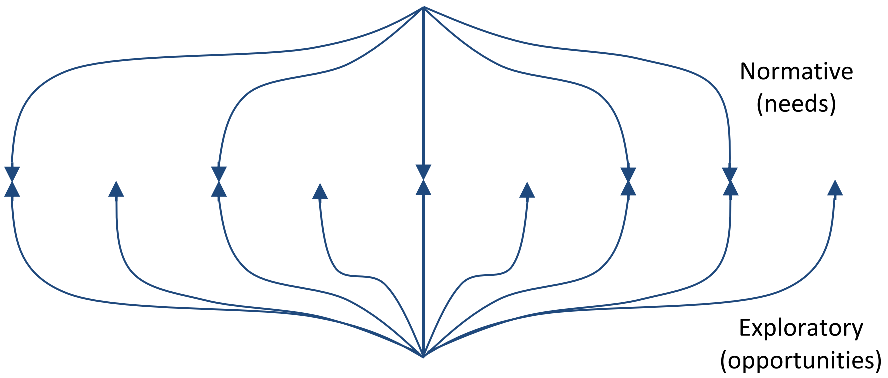

Figure 13. *TF is more functional when joining exploratory and normative components (Adapted from Jantsch 1967).*

The reason for the previous may be that exploratory methods do not take advantage of non-technical areas. Normative methods however, attempt to predict the influence technology will have on the future. In other words, exploratory methods forecast future technologies and normative methods try to assess the impact these technologies will have. As mentioned at the end of Section 2.1, the most important pay-off from TF is not technology itself, but its applications. It would then seem that the combination of exploratory and normative components would pave the way for truly useful TF, where possible applications of future technology could begin to take shape.

To summarize, it has been mentioned how forecasting can be approached either in exploratory or normative manner, meaning projecting from the present into the future, or starting from future assumptions and projecting them into the present. On the other hand, it was also pointed out how methods can be quantitative or qualitative, meaning they either rely on historical data or on expert knowledge.

2.5 Most common methods

The previous section discussed approaches and method classification. This section discusses forecasting methods. Accepting the premise that change is inevitable is not enough to secure the survival of a company; it has to be an active participator for the change. According to Brownlie (1992), the following are the basic notions that are worth answering before actively embarking on TF:

- Identify sources of future change in the business environment
- Anticipate the nature of such change and the strategic issues that might emerge
- Assess how the conditions for successful business will change as a result
- Plan and implement which guide the company towards the desired future

From these steps a lesson from Section 2.3 can be inferred, which is how TF might be inherently related to R&D, but business planning and direction is just as important, with top management as the main driving force. Nevertheless, there is a more important matter behind this list. By answering these notions, the firm could already identify whether exploratory or normative forecasting would be the starting point. The reason why the term “starting point” is used is because it should not be forgotten that a combination of both approaches yields the best results, as mentioned in Section 2.4.

The previous steps do not yet answer the question of how to best select a forecasting method. Choosing the right method to perform TF might just be trickier than what one would think. According to Bouwman & van der Duin (2003), factors that influence the choice of a specific method are:

- Level of uncertainty
- Time horizon
- Types of variables under analysis
- Participation
- Duration
- Cost
- Phase of innovation

A thorough breakdown of most existing forecasting methods and the way to perform them will not be shown. The purpose of this section is to give the reader an understanding of some of the different methods there are. The reason for this is that the central idea behind this thesis is to complement forecasting methods with the inclusion of elements that have not been considered before, ultimately creating a roadmap that gives technological forecasters a new way to “create” or forecast innovation. For a deeper understanding of forecasting methods, there is a plethora of material available easily available in journals and other similar online publications.

The previous section mentioned how forecasting can be approached either in exploratory or normative manner, and how methods can be quantitative or qualitative, but actual methods remained unmentioned. In broad terms, most quantitative methods are just variants on simple trend extrapolation procedures (Cetron, 1969). Extrapolation methods are basic to forecasting; they consist of mapping or graphing historical available data and project the data beyond it will look like based on detectable patterns and trends. Cetron believes newer methods could be seen as sophisticated evolutions of extrapolation.

Some of the literature reviewed for this thesis (Cetron 1969; Cetron & Ralph 1971; Coates et al. 2001; Daim et al. 2008; Martino 1993; Mishra et al. 2002; Porter & Watts 1997) either mention forecasting methods or use them as a part of their studies. Some authors may call methods slightly differently. In other cases, variations of a method are mentioned under the same name. Table 3 shows these methods.

Table 3. *A collection of forecasting methods mentioned or used by some authors.*

	Cetron 1969	Cetron & Ralph 1971	Coates et al. 2001	Daim et al. 2008	Martino 1993	Mishra et al. 2002	Porter & Watts 1997
Analogies	✓				✓	✓	✓
Cross impact analysis		✓				✓	
Delphi	✓	✓	✓		✓	✓	✓
Committees			✓				✓
Growth models/growth curves	✓		✓	✓	✓		✓
Modeling		✓	✓			✓	
Monitoring and scanning			✓				
Patent analysis				✓	✓		✓
Pattern analysis							✓
Poll, panels	✓	✓					✓
Relevance trees			✓				
Scenarios			✓		✓	✓	✓
Simulation			✓				
Technology cycle time				✓			
Trend correlation	✓	✓	✓	✓	✓		

These methods will not be individually described, as mentioned in the previous page, it is not central to this thesis. In order to simplify the understanding of the previous table, they will be classified. Methods are classified differently by each author, although they share some commonalities. According to Martino (1999), there is one frequently used classification which groups them into six different types:

- Extrapolation
- Leading indicators
- Causal models
- Stochastic (probabilistic) methods
- Delphi
- Expert opinion

Martino (1999) describes these method types in the following way. First, extrapolation assumes the future of a time series is captured by the past of that series, which only needs to be extended. Second, leading indicators work under the premise that certain patters can be found in the deployment of specific technologies, observing such a pattern at early stages can become a leading indicator for later stages. Third, causal models assume that there are relevant variables and their linkages are known and can be described in mathematical models. They are sporadically used by technology forecasters, as defining the variables, let alone finding linkages is very problematic. Fourth, stochastic methods differ from the others. The previous three methods produce a single-point forecast, whereas stochastic methods give a range of values for the outcome and the probability distribution for that range. (Martino 1999)

The fifth and sixth types, Delphi and expert opinion, stand on the opposite end of the spectrum per se. The Delphi method consists or several structured rounds of experts sharing opinions and trying to sway each other, without knowing who the author of each opinion being discussed is. Expert opinion, as it name says it, consists of committees or panels, where experts openly discuss TF based on their knowledge and expertise.

This section has presented different forecasting methods as well as a classification system, the next natural step would be to pair them up. Table 4 displays the methods mentioned in Table 3 classified according to the categories mentioned by Martino. It is worth noting that the table is purely an interpretation; it is not an indisputable truth.

Table 4. *The methods classified according to Martino.*

	Extrapolation	Leading indicators	Causal methods	Stochastic	Delphi	Expert opinion
Analogies	✓			✓		
Cross impact matrix				✓		
Delphi					✓	
Committees						✓
Growth models/growth curves	✓					
Modeling			✓			
Monitoring and scanning					✓	✓
Patent analysis	✓			✓		
Pattern analysis		✓				
Poll, panels						✓
Relevance trees			✓			
Scenarios			✓		✓	✓
Simulation		✓		✓		
Technology cycle time	✓					
Trend correlation	✓					

These (or any other) methods are rarely used purely, meaning most often forecasters use a combination of methods, which explains why some methods can be classified under more than one category. The Delphi method deserves a specific mention. Some authors consider it a mere variation of expert opinion, but there is much more to it. According to Martino (1993), Delphi has three characteristics that set it apart from any other face-to-face group interaction, which are: anonymity, iteration with controlled feedback and statistical response. Anonymity is key because when members of a group do not know which member contributed a specific statement or opinion, a great deal of bias is out the picture. Iteration means that the process has several stages. Finally, statistical group response means that the opinions of the entire group are considered.

The Delphi method consists of a panel of experts in the area being forecasted and a moderator. The panelists should be more knowledgeable in the area under scrutiny than the moderator (Martino 1993). Figure 14 presents the basic Delphi process which consists of four rounds.

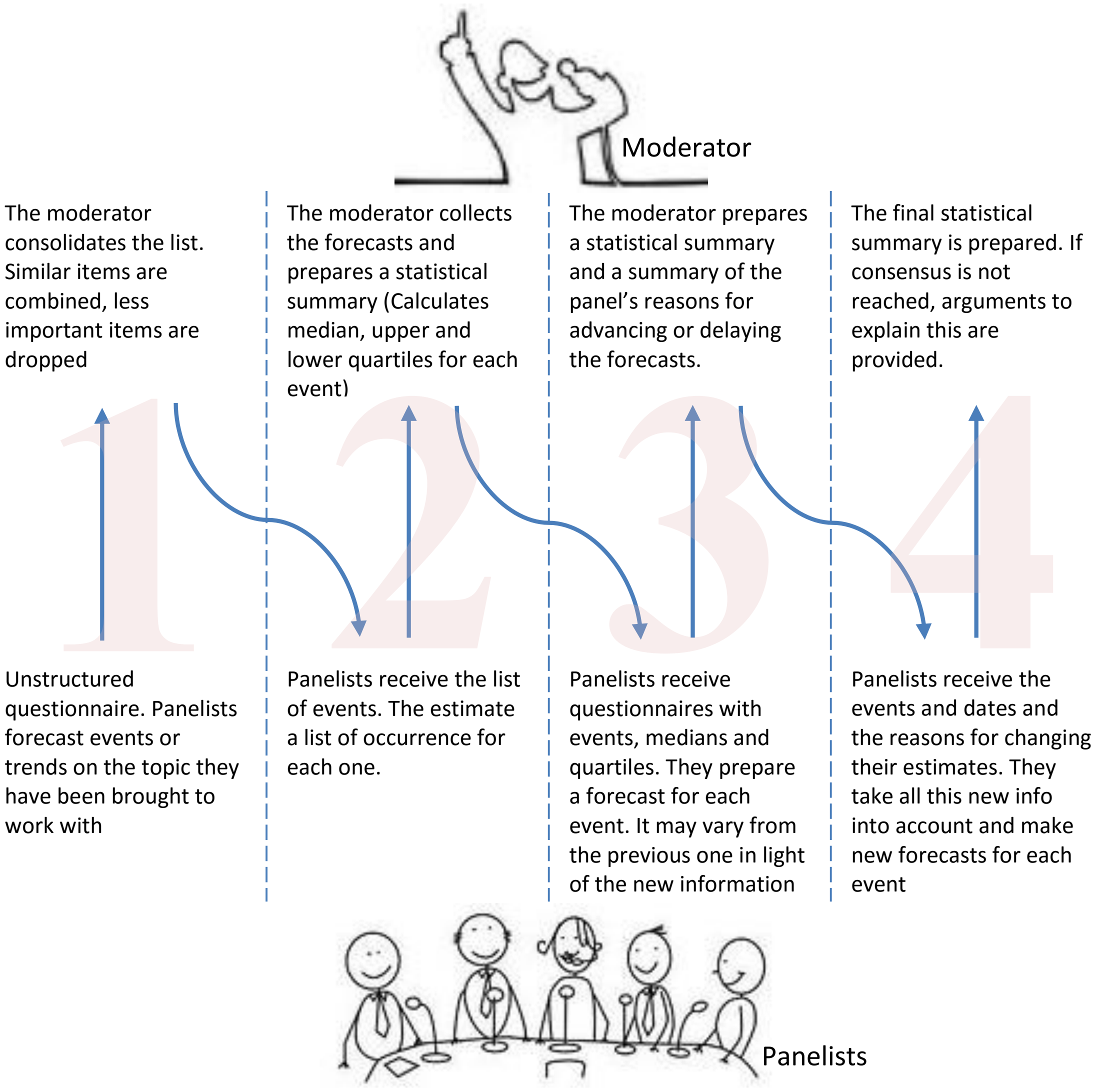

Figure 14. *The basic Delphi process.*

It is important to properly define the term questionnaire in this context. In Delphi, a questionnaire provides much more than just questions; it also offers information to the members about the degree of consensus and arguments presented by other members. The reason why Delphi is described more thoroughly than any other method is because it is significant to this thesis and the project behind it. This will be discussed in more detail in Chapters 5 & 6.

2.6 Limitations, shortcomings and areas of opportunity

Technological forecasts can provide crucial information for decision makers. Even though forecasting has been widely developed, it is not able to answer every question regarding technology and the future. On a similar note, sometimes best practices can be collected from other sources. This section mentions some notions of interest that could be beneficial to achieve good practices of TF.

In order to be able to forecast a technology, that technology must be clearly understood. Most importantly, key parameters, which will be forecasted, should be defined. Sometimes forecasters overcome the difficulty of tracking a parameter by focusing on a subset of parameters (Anderson et al. 2010).

An example of the previous statement could be the following. Instead of focusing on the cost of airplane travelling, forecasters could focus on the evolution of the performance of jet turbines, the amount of fuel burned per kg, the increasing costs of jet fuel and so on.

Another area worth mentioning is the prediction horizon. Section 2.4 mentioned exploratory and normative approaches. But whether the forecaster intends to start in the present and project into the future or vice versa, it does not yet tell how to select a suitable timeframe. There is simply no “correct” prediction horizon, it varies from industry to industry, the media industry has a short horizon, while the oil industry has a horizon that exceeds 20 years (Bouwman & van der Duin 2003; Brownlie 1992). These are standard horizons for normal operations within the industry, but they are not by any means a rule. An institution may very well select any type of forecasting horizon according to need or desire. Porter & Watts (1997) suggest that, in order to effectively engage in TF, the firm must look into past stories of failures just as much as of success, from the firm itself and the industry alike.

There are common errors or misconceptions that should be avoided when engaging in TF activities. According to Mishra (2002) there are four lessons to keep in mind:

1. Avoid over optimism when timing the market success of new technologies
2. The practical use of new technologies, i.e. its applications, happens often in unforeseen ways

3. Reduce attempts to predict the social repercussions of new technologies
4. Include economic and historical analysis for each innovation

The previous list could be considered as limiting aspects, guidelines that could increase the chances of a successful forecast. Ignoring these guidelines on the other hand, could represent a major setback. For a more detailed list of the limitations of technological forecasts refer to Appendix 1.

In the past, companies have committed terrible mistakes by trusting on TF that never materialized. It is not uncommon for forecast to be over-inflated because even with the highest of expertise, experience and historical data, the judgment of the forecaster is critical, yet they are vulnerable to hopes, expectations and even hunches. (Wheeler & Shelley 2010)

When trusting decisions on TF, which can be perceived as inaccurate, it is recommendable to take a conservative stand. The previous does not imply experts should not be consulted; it simply highlights the complexity of TF and how at times even specialist might struggle for accuracy.

A way to improve the extent to which TF helps is the inclusion of scenarios. Scenarios as such were mentioned as a forecasting method in Table 3. The concept behind scenarios could be used as an additional tool in TF. Bouwman & van der Duin (2003) assess scenarios the following way. TF shows the main trends in a specific technology domain while scenarios cover the possible future worlds. A clear example of this is Shell, the oil giant was able to anticipate the oil crisis of 1973 by including a set of scenarios of the possible shortage of oil supply due to political tensions in the Middle East and the increase in oil prices that ensued shortly afterwards. (Bouwman & van der Duin 2003) Sometimes scenarios can provide information which could otherwise be ignored. Furthermore, they help TF by adding political, economic and socio-cultural aspects into the mix.

From a different perspective, TF could be seen as an extrapolation of extrapolations that begin in the past with the assumption that these will carry on into the future. After a given length of time, it is not possible to extend that line, at least not reasonably because of the extensive lack of certainty. It is at this point, when scenarios can be utilized to explore the future. This is seen in Figure 15.

The purpose of mentioning scenarios is not to give the reader extensive knowledge on the topic, but only to show how, rather than just a method of TF, scenarios can be used as a supplementary tool. The inclusion of scenarios at the end of TF through, for instance, extrapolation methods, could shed new light on the forecasted data. This opinion will play a role in the main framework of this thesis. From the point of view of the forecasting approach, the inclusion of scenarios after forecasting results would be more suitable for exploratory methods.

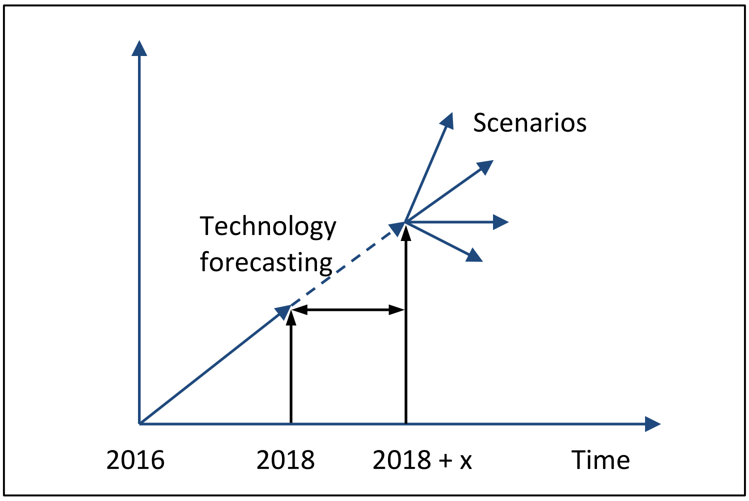

Figure 15. *Combining technological forecasting and scenarios (Adapted from Bouwman & van der Duin 2003).*

Though perhaps not a priority, one more factor to consider in innovation and TF is the sociocultural aspect. Though not a limitation as such, it is worth considering. Coates et al. (2001) give an example of it. They assert how, for instance, most people have a poor understanding of advancements such as genetically engineered foods, human genetic manipulation and brain science. These could be perceived as a risk to people or the environment or a threat to traditional or religious values. For such sensitive subject a more humane touch might be needed, but this is outside of the scope of TF. Though it is particularly tricky, a different approach with customer value in mind could perhaps help alleviate these issues. Nevertheless it must be stated that relieving sociocultural angst is not the purpose of customer value analyses.

Finally, one last consideration that is important is the rate of success of forecasts according to their area. Conforming to a study of Fye et al. (2001), where 201 forecasts were analyzed, the highest number of successful forecasts were done in the field of computer and communication technologies. The authors claim the small sample sizes precluded them from reaching statistical conclusion. While this cannot be considered a limitation, it certainly dictates the complexity of forecasting a certain given technology. A detailed chart of the success rate of forecasts per according to the study performed by Fye et al. can be seen in Appendix 2.

After all of what has been discussed in this chapter only one thing can be said. TF is not an exact science, there is no single correct answer, no magic formula and there will always be room for error.

2.7 The missing link

The literature reviewed in this chapter is extensive but it has one unison focus, technology for the sake of technology. Section 2.4 elaborated how the biggest pay-off from TF is not the technology itself, but the technological applications that derive from it. The previous being said, there are no tools that could guide a structured process of customer-centered technology exploration from the beginning, i.e. the very initial steps of TF.

Nowadays, most, if not all of the activities of a company are focused around customers and their needs. Product design has become more customer-centered in recent years, though this is merely design parting from technologies born through regular TF. Product manufacturing is done with the best interests of the customer in mind. With increasing competition, sales are not possible unless the product offer is tailored to the needs of the consumer. With all of the main processes of a company tailored to best serve the interests of the customer, TF should be no different, but as has been shown, this is far from the truth.

Section 2.4 presented normative forecasting, where future needs are evaluated and then brought to present day. A spin to this approach could already, at this early stage, present the first approximation of customer value-based technology forecasting. Instead of using the normative approach for policy making, this change of focus would suppose an attempt at evaluating future customer value and bring it to the present. This way, in conjunction with an exploratory approach, the technologies that could fulfill these potential future needs could be forecasted. This is shown in Figure 16.

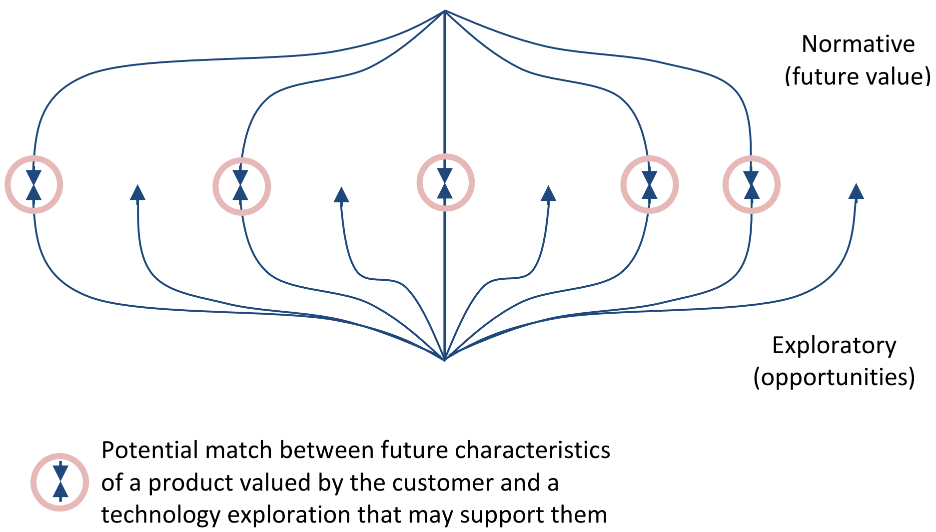

Figure 16. *Customer value based normative forecasting (Adapted from Jantsch 1967).*

This thesis has two main foundations on which its framework will be built: technology forecasting and customer value. This chapter examined the first to a certain degree of thoroughness, some aspect were left unexplained as it was clarified that they play no role in the context of this report.

First, the concept of TF was introduced and its need was defined, however this approach did not surpass technological need. Second, a brief history about TF was given. It was emphasized how technology was driven largely by war, until globalized commercial competition took the role as the driving force in the 90s at the end of the Cold War. This fact alone introduces the need of knowing what a customer really desires. At the end of the war technology was no longer driven by pure technical superiority, instead, the need for ingenious applications of technology that satisfy user needs was introduced, opening the door to a different type of TF. Third, the responsible entities behind TF were discussed. The importance of top management was declared and a list of important stakeholders was done according to relevance, it became apparent, how customers can further play a role in technology, rather than just end consumers, they can become active stakeholders, which begins to break the “only experts” paradigm.

Section 2.4 described the elements of a forecast, as well as the approaches and types of forecasts. Section 2.5 built up on this, by actually discussing common forecasts methods in existing literature and categorizing them according to one of many existing classification. Section 2.6 wrapped this chapter up by bringing to attention how TF as a study has weaknesses and room for improvement. Though the innovation roadmap has not yet been introduced, some aspects that differ from typical TF, such as the consideration of customer needs and scenarios already highlight the need for customer oriented TF. Most importantly, the final section of this chapter demonstrated how the available literature on TF rarely takes customer value into consideration, and even when it does, it is in a rather superficial manner; this further brings forth the need of a customer value-oriented TF.

3. CUSTOMER VALUE AND TECHNOLOGY FORECASTING

3.1 Defining customer value

Single-brand loyalty is a concept common to the generations of our fathers and grandfathers. Nowadays this has been replaced with loyalty to multiple brands within one category. Because of this divided loyalty, more customers give more of their business to competitors. (Keiningham et al. 2014) With customers spending their money over a larger array of offerings, companies find themselves in the dire need of offering the customer what they truly need. Customers are the source of all business growth, yet more often than what would be expected, companies do not know what their customers really value (McDougall et al. 1997). Understanding how customers perceive value is a key competitive advantage (Woodruff 1997). Understanding and delivering superior value to customers is key to generating and sustaining long-term relationships (Ulaga & Chacour 2001).

Companies that try to understand the needs of their customers will do better than those who just push products onto the market. In the same manner, forecasters who understand the factors that affect the choices of consumers can do a better job. (Wheeler & Shelley 2010) What the previous statement rudimentarily says, is the need to understand customer needs in order to offer the best possible solution. Without an explicit mention, this can already be related to the concept of customer value.

The previous, while somewhat obvious, can be more difficult to follow than expected. Anticipating the factors that affect consumer choices can be relatively simple in the short term, but when forecasting several years down the road, consumer choices can become a blur. So, when forecasters speculate about long-term technologies and their applications, it is understandable when consumer needs are neglected in order to focus on technology.

According to Brownlie (1992) TF with a timescale upwards of 5 years generally falls under technology push. This is a sensible assertion, trying to predict for the medium and long term implies something that might not yet be in existence, shown in Figure 17. It is precisely because of this statement that the concept of customer value gains importance.

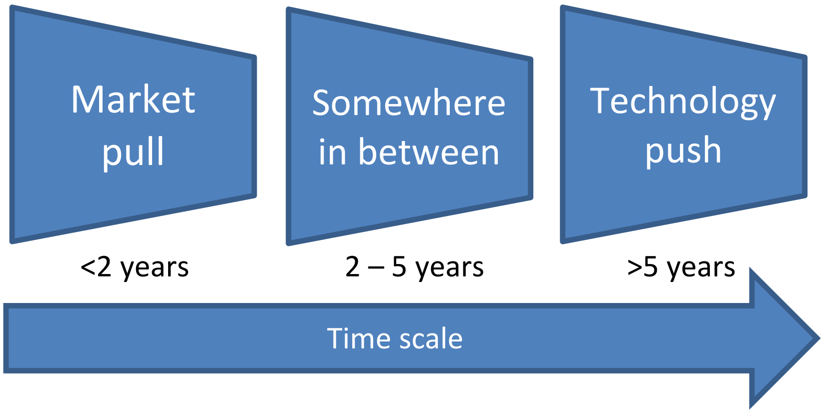

Figure 17. *Orientation of user needs in TF according to time scale (Adapted from Brownlie, 1992).*

Creating and delivering superior customer value is considered a cornerstone of B2B marketing (Keränen & Jalkala 2013). By considering how to offer value and worth to a customer through a potential innovation being forecasted, the barriers of entry could be lowered, the adoption curve could be shortened and the costs of educating adopters could be reduced. By way of explanation, the purpose of considering customer value in TF is to in a way, begin the move, or emulate one, from technology push to market pull even in long-term forecasts.

The value of a product offering in a given application is considered as the cornerstone of the marketing strategy (Anderson el al. 1993). Due to the vital nature of value in business markets, it is essential for managers to estimate the value of their products in particular customer applications and learn how it can be enhanced (Wind 1990; in Anderson et al. 1993).

A similarity in concepts can be identified. The previous paragraph mentions the importance of value in product applications. The previous chapter clarified how the biggest pay-off from technology forecasting is not technology itself, but its applications. Though still early, this can be an entry point for the mash-up of these two concepts.

It is important to recognize that the literature on customer value is vast as a part of business marketing. However, customer value as such is always analyzed in current or existing product offerings, or in the worst case, in almost ready-to-market products. In other words, it has not been applied to future non-existing technologies, products or services.

During this chapter, as different aspects of customer value are discussed, they will partly be approximated to the context of technology forecasting. This way, the framework of innovation roadmap can be introduced in a more logical fashion in Chapter 6.

Customer value has been defined several times by different authors. Table 5 shows some definitions encountered during the literature review of this thesis.

Table 5. *A collection of definitions of customer value.*

Definition	Author
The perceived worth of monetary units of the set of economical, technical, service and social benefits received by a customer in exchange for the price paid for the product offering , taking available alternatives into consideration.	Anderson et al. 1993
The emotional bond established between a customer and a company after the customer has used a product or service produced by that supplier and found that the product provided and added value.	Butz & Goodstein 1996
The trade-off between customer-perceived quality and customer-perceived price.	DeSarbo et al. 2001
The difference between the benefits and sacrifices (monetary plus non-monetary costs) perceived by customers.	LaPierre 200
The monetary value of the economic, functional and psychological benefits a customer expects when purchasing a good or service.	Lyly-Yrjänäinen et al. 2010
The overall assessment the customer makes of the utility of the product based on perceptions of benefits received and sacrifices made.	Menon et al. 2005
The outcome of perceived product quality against perceived sacrifice.	Monroe 1990 in Sweeney et al. 1999
The entirety of benefits received minus the costs sustained by the customer in securing a product or service.	Treacy & Wearsima 1995; in Khalifa 2004
The trade-off between benefits and sacrifices perceived by the customer in the offering of a supplier.	Ulaga & Chacour 2001
The overall assessment of the consumer of the utility of a product based on perceptions of what is received and what is given.	Zeithaml 1988

All of the definitions presented in the chart have elements in common. They mention a customer who acquires a product or service with the expectation of receiving a set of benefits or rewards. In order to rip these benefits they have to be compensated with sacrifices or costs. This trade happens under the premise that the benefits far outweigh the costs, pictured in Figure 18.

Benefits – Costs = Customer value

Where Benefits > Costs

Figure 18. *A definition of customer value.*

It is vital to understand that the benefits must be greater than the costs, otherwise the customer would not enter the transaction to acquire the good or service, under normal circumstances at least. The benefits and costs mentioned in this figure will be described in the next section.

One notion that should be clear to everyone is that customer value is determined by the perceptions of the customer and not by the assumption or intentions of the supplier (Belasco & Stayer 1993; in Khalifa 2004). Proving customer value is essential. An offering may offer superior value, but if the firm does not demonstrate it and document it with a claim, customer will dismiss it and that offering may never make its way to the end user (Anderson et al. 2006). Even when discussing future offerings through TF, potential value is something that should be thrown into the mix.

Now that the essence of customer value is understood, it is vital to know how to offer it. Anderson et al. (2006) mention three different kinds of value propositions. The first one is "all benefits" where the firm simply lists all the benefits it believes their offering might deliver to the customers. The more, the better. The second one is "favorable points of difference". In this case the firm acknowledges there is an alternative and they emphasize how the elements of their offering are better than those of the alternative. These elements become the points of difference. Third and last there is "resonating focus". This is similar to the previous, except that the firm recognizes their solution does not have to beat the alternative in every single point of difference. Instead, there is a point of parity, i.e. an element where the offering is as good as the alternative, and one or two points of difference, which truly deliver superior value. Each of these solutions requires more understanding of the competition than the previous one. Table 6 further describes these value propositions in order to achieve a better understanding of them.

Table 6. *The three value propositions (Adapted from Anderson el al. 2006).*

Value proposition:	All benefits	Favorable points of difference	Resonating focus
Consists of:	All the benefits customers receive from the offering	All favorable points of difference the offering has in relation to the best next alternative	A point of parity and one or two points of difference which deliver the greatest value for the foreseeable future
Answers the customer question:	"Why should we buy your offering?"	"Why should we buy your offering instead of the competitor's?"	"What is most meaningful to keep in mind about your offering?"
Requires:	Knowledge of own offering	Knowledge of own offering and the next best alternative	Knowledge of how own offering delivers superior value to the customers, compared to the next best alternative.

As can be appreciated in the chart, when moving to the right, the propositions become more comprehensive and complex. A deeper understanding of the competition and the needs of the customer becomes necessary. As tricky as it might be, this chart should be put in terms of TF. When thinking of projecting customer value into the future, little is known about the competitors and the needs of the customer. Even though TF is sometimes performed to anticipate the innovations of competitors, they cannot be taken as a given as the uncertainty is too high. It is for this reason that the only value proposition suitable for TF is “all benefits”.

3.2 Measuring customer value

Butz & Goodstein (1996) defined customer value as an emotional bond between the customer and the company. The emotional bond created leads to the customer buying repeatedly, or even better, exclusively from that supplier. This bond requires that the good or service provided by the organization regularly meets or exceeds the expectations of the customer. (Butz & Goodstein 1996)

One of the simplest manners to measure customer value is through net customer value. Rather than a model, this can be seen as an introduction to measuring customer value. According to Butz & Goodstein (1996), net customer value can be defined as the value that the customer itself intuitively calculates based on his/her own values and beliefs. The product purchased must provide more benefits to the customer that the costs incurred. (Butz & Goodstein 1996) This is illustrated in Figure 19.

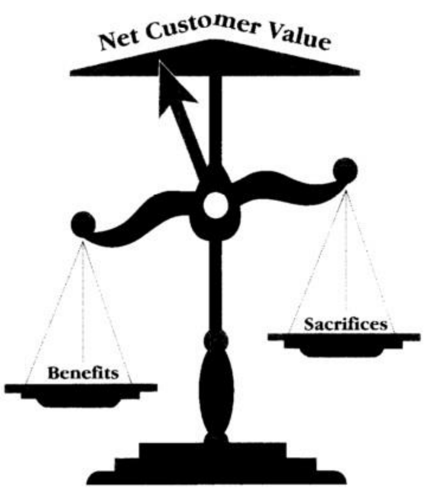

Figure 19. *Net customer value (Butz & Goodstein 1996).*

Customers may even unknowingly calculate this net customer value. Guaranteeing this value is a priority for firms because it is what keeps the customers coming back rather than resorting to the competition.

Customers in reality may not perceive value as elegantly as companies do when trying to deliver superior offerings to the customer. Sweeney et al. (1999) harshly say that the greater the functional and technical quality of the offering, the greater is the perceived value from the eye of the customer. Similarly, the greater the perceived product quality is, the greater is the perceived value.

Although customer may define or think of value in a more rudimentary way, the previous definition can be extended. A study performed by Zeithaml (1988) found that customers typically describe value in four different ways, they are:

- Value is low price
- Value is whatever I want in a product
- Value is the quality I get for the price I pay
- Value is what I get for what I give

The first salient is related to "getting your money's worth". The second relates to purchasing a product of superior quality. The third refers to the price-quality ratio. The fourth and last makes allusion to how much use the customer can obtain out of the purchased good.

One more tool that offers understanding on how value is perceived from the customer point of view is the customer value hierarchy model. Woodruff (1997) asseverates that customers perceive value in a straightforward manner. A customer typically associates product attributes with consequences, benefits and personal values. This hierarchy model is shown in Figure 20.

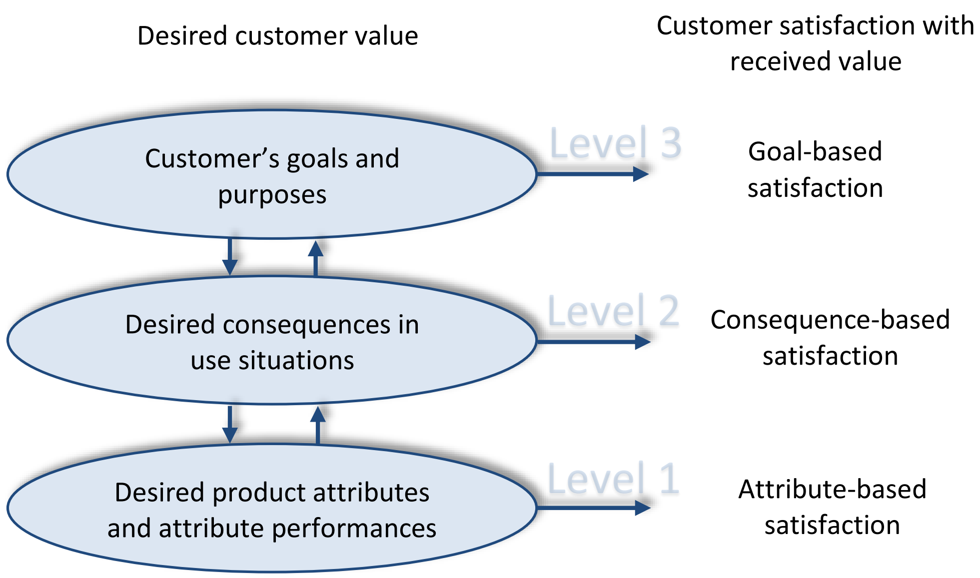

Figure 20. *Customer value hierarchy model (Adapted from Woodruff 1997).*

Woodruff (1997) describes the model as follows. At the bottom of the hierarchy, customers learn to think of products as bundles of particular attributes and attribute performances. On the second level, when using a product, the customer forms preferences for certain attributes based on their ability to facilitate achieving desired consequence experiences, reflecting value in use. Finally, customers learn to desire certain consequences according to their ability to help them achieve their goals and consequences. (Woodruff 1997)

When analyzing the model from bottom to top, initially, customers assess a product based on their attributes and what those attributes are capable of doing. As customers become more acquainted with the product, whether by use or when thoroughly researching prior to purchasing it, they begin to develop an attachment to what that product can do. Finally, the customers realize the impact this product may have on their lives and goals, namely, the real value it provides to them.

Customer value is perceived by the customer, rather than determined by the seller (Woodruff 1997). This means a company does not determine how valuable a product is, instead, the customer does according to his/her satisfied needs. That being said, it is necessary for companies to understand how this value is perceived by the customer in order to offer superior offerings.

Customer value, as asserted from the point of view of companies, has more elements to it. When calculating value, it is important to know what is being calculated specifically. Butz & Goodstein (1996) specify how customer value has three different levels. They are as follows:

- Expected value
- Desired value
- Unanticipated value

The first one is the basic that is normal to the industry, the minimum level customers will accept. Desired value are features that add value for the customer but are often not expected because of the industry standards. The last level, unanticipated value, is where the organization finds ways to add value beyond of the expectations or desires of the customer, put differently, customers are positively surprised to a large extent with features they could not have envisioned themselves.

Khalifa (2004) describes Cano’s model where these three levels are described as components of value under different names. Expected value are called dissatisfiers, desired value are satisfiers and unanticipated value are delighters. The authors differ in the definition of one of them. Whereas Butz & Goodstein state how desired value is often unexpected because of industry standards, Khalifa unequivocally says how satisfiers are explicitly requested and expected by the customer. The model is pictured in Figure 21.

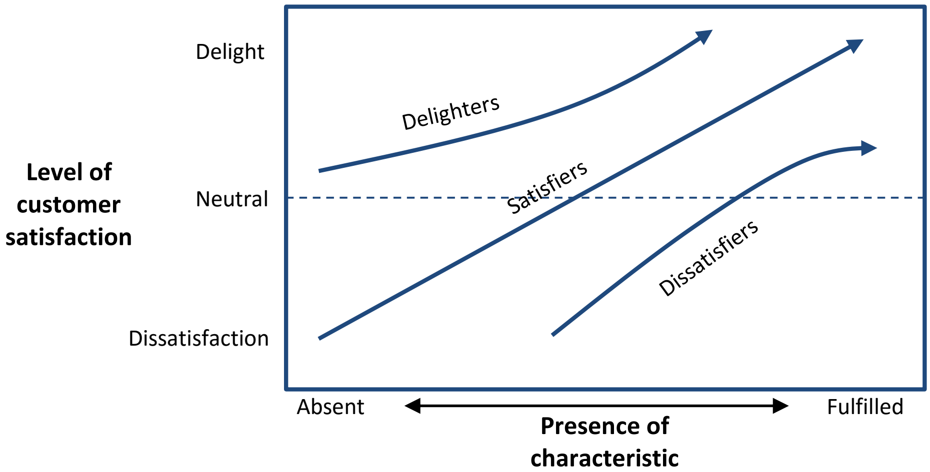

Figure 21. *Kano's model of customer perception (Adapted from Khalifa 2004).*

Based on the definitions of both authors, it can be deducted that dissatisfiers are the basic values that are needed and taken for granted. Satisfiers begin to offer actual value, while delighters set customers to a state of overjoy. In order to guarantee customer satisfaction, the firm should make satisfiers their preset standard and aim for delighters.

As mentioned in the previous section, Lyly-Yrjänäinen et al. (2010) attest that customers receive economical, functional and psychological values or benefits from an offer or service. In order to receive these benefits, a customer must incur into costs. These are purchase, usage and disposal costs. The difference between the sum of benefits and the sum of the costs is the perceived customer value (Lyly-Yrjänäinen et al. 2010). This can be seen in Figure 22.

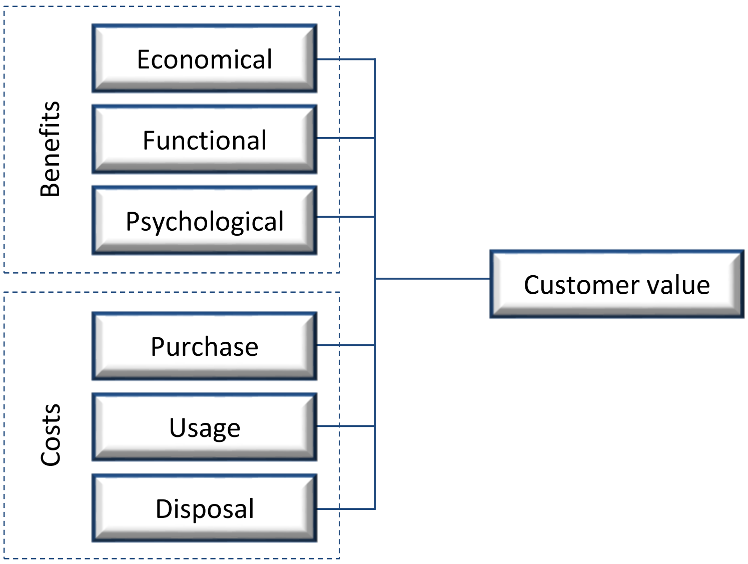

Figure 22. *Customer value as a function of benefits and costs (Adapted from Menon et al. 2005).*

These benefits and costs can be described, e.g. with an individual who buys a brand new set of top of the line tires along with a set of aesthetic rims. The benefits could be getting better fuel economy (economic), having a safer ride (functional) and getting a better look for the car (psychological). The costs would be cash exchange for the tire (purchase), paying a professional to rotate the tires or fix a flat when necessary (usage) and throwing the tires away in accordance to environmental regulations once their useful life has come to an end (disposal).

Figure 22 begins to depict how customer value can be measured, but there is one entity that is not yet mentioned, the company who makes the offering. Customer purchase goods because of the value they expect, while companies and sell them for a profit. This relationship is explained in Figure 23.

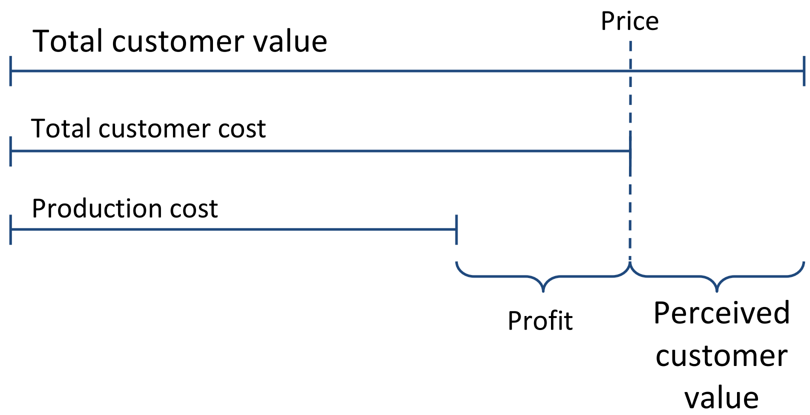

Figure 23. *The relationship between perceived customer value and profit (Adapted from Lyly-Yrjänäinen et al. 2010).*

When consumers make a purchase decision, they consider not only instant factors, such as price and service, but also longer-term implications of the ownership of the product (Sweeney at al. 1999). The aforementioned costs are entirely monetary. According to Grönroos (1997), a customer pays for a product with more than just money. An important cost that is not always considered is the psychological cost. These costs are caused by the fact that the customer fears that problems with the product or service will occur, which leads to a situation where he/she cannot fully concentrate in his/her duties. This cost is easily perceivable but it cannot be measured. (Grönroos 1997)

To better understand psychological costs a remark can be made. Many authors reiterate how sacrifices are made upon purchasing a product or service. According to Sweeney et al. (1999), when buying a product, consumers take a chance that the purchase will deliver the satisfaction they expect over time. This potential sacrifice is a risk. The higher this perceived risk, the more consumers must gamble in buying the product and thus the higher fear from the customer that the purchase will perform. (Sweeney et al. 1999) Figure 24 shows what the model from the previous figure would look like when adding this breakdown of benefits and costs.

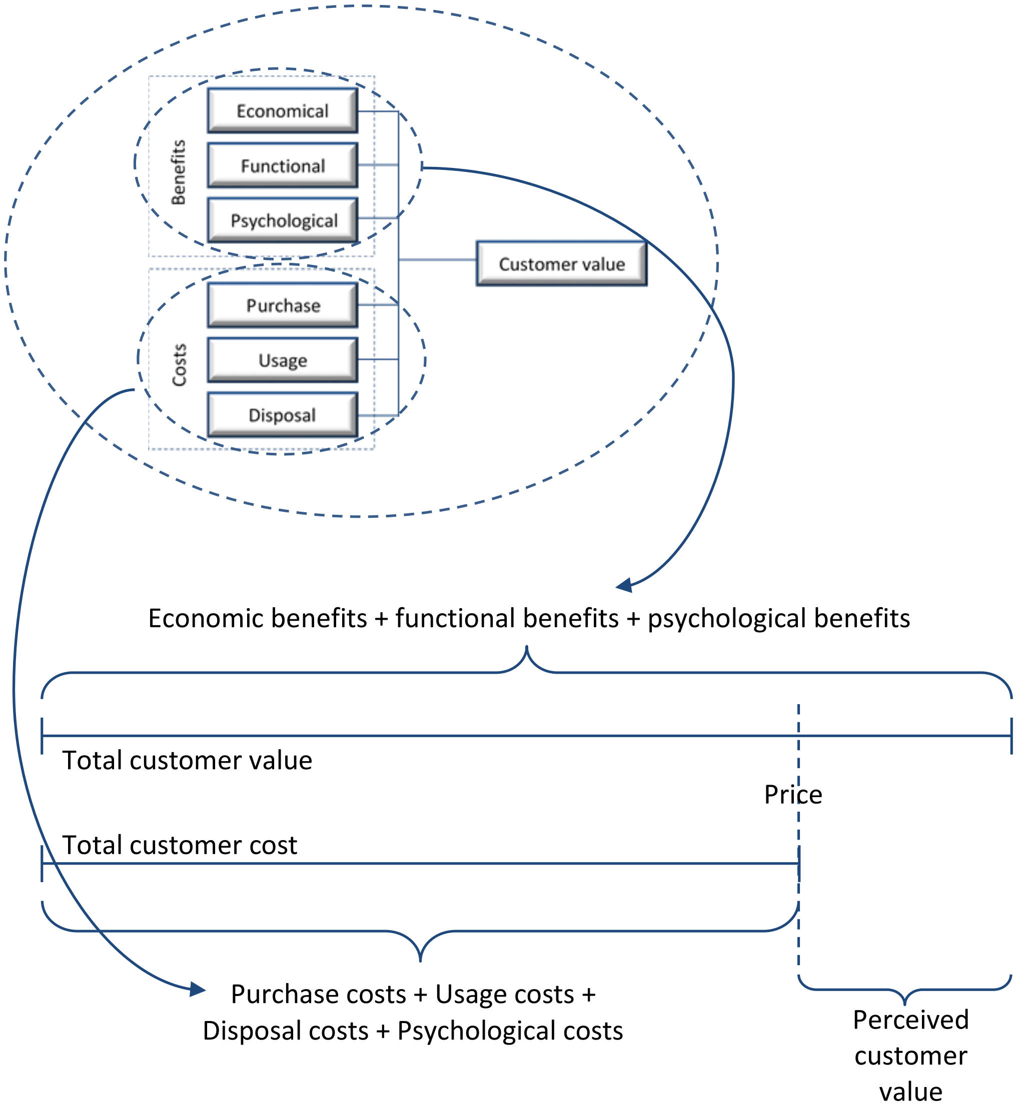

Figure 24. *The breakdown of total customer value and customer cost (Adapted from Lyly-Yrjänäinen et al. 2010).*

So far, this section has introduced two main concepts for measuring customer value. Kano's model of customer perception and perceived customer value as a function of value and cost elements. Figure 25 merges these two concepts.

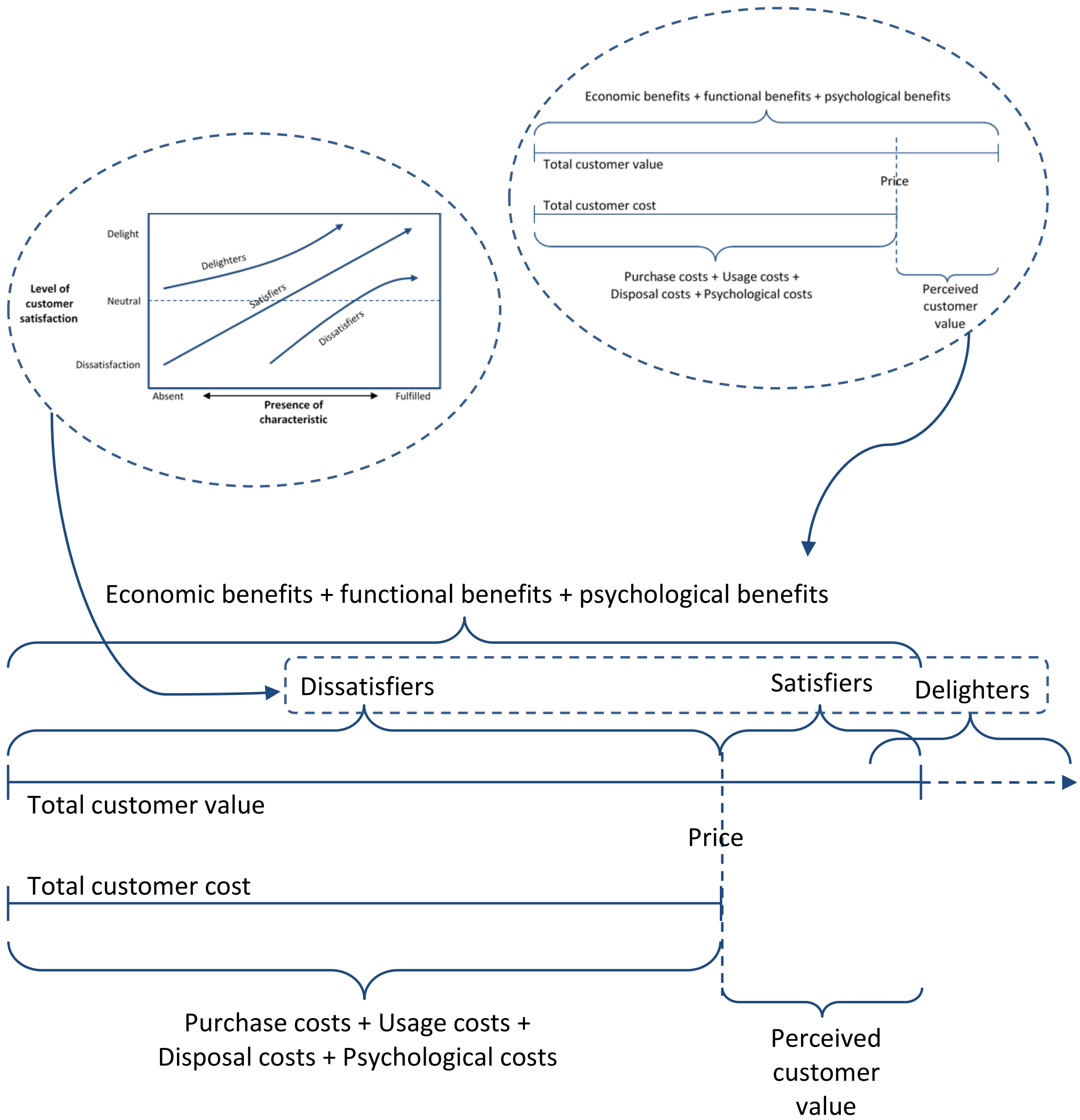

Figure 25. *Kano's customer perception as a part of total customer value.*

The arguments behind the dissatisfiers, satisfiers and delighters is the following. Dissatisfiers are the minimum set of characteristics needed to convince the costumer to purchase the product, if these are not met, then there would be no transaction. For this reason, dissatisfiers roughly equal total customer cost. Perceived customer value is the willingness-to-buy of a person (Monroe 1990; in Sweeney et al. 1999). Satisfiers are what keep customers happy, they are the reason why customers choose one product over the other, and hence satisfiers are equal to the perceived customer value. Delighters are attributes that may not yet exist or that might be completely foreign to the customer; as such they cannot be considered as an existing part of the value. Delighters have the potential to increase the amount of total and perceived customer value. The line where dissatisfiers end and satisfiers begin is blurry, meaning a direct comparison to total customer cost and perceived customer value should not be taken as fact, but the bigger picture tells how customer value can be measured in terms of these three elements, as was depicted in the previous image.

3.3 Customer value assessment

Customer value assessment can be described as the process of evaluating and communicating the value created for customers (Payne & Frow 2005; in Keränen & Jalkala 2013). The previous section discussed the way in which customer value can be measured. Once it has been measured, it should be assessed i.e. verified to make sure the findings are correct or on the right track at least, after which it can be communicated to the customer. Keränen & Jalkala (2013) have identified five key processes in customer value assessment and describe them as follows:

1. Value potential identification - Understanding how a company can add value to the business of its customer
2. Baseline assessment - Assessing a customer current situation prior to deploying the offering of the company
3. Performance evaluation - Evaluating the impact the offering actually has on the business of the customer
4. Long-term value realization - Ensuring that customers have in fact received the promised value
5. Systematic data management - Collecting relevant customer data from all the previous steps

The fifth element ties the previous steps together. The first three elements are carried out before delivering the offering to the customer, the third and fourth elements are executed after the offering has been delivered. This is visualized in Figure 26.

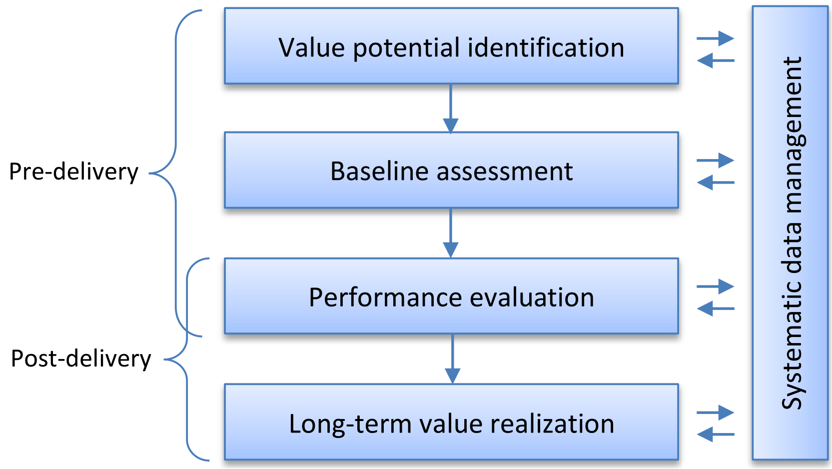

Figure 26. *How the five key processes of customer value assessment interact (Adapted from Keränen & Jalkala 2013).*

In order to relate these key processes to the realm of TF, some of them have to be eliminated. Only pre-delivery items can be considered for the obvious reason that forecasted technologies will not exist in the immediate future, hence they cannot be delivered. From the three pre-delivery processes, performance evaluation will be dismissed as the uncertainty linked to TF makes it particularly difficult. As a result, there are two key processes that assess customer value in TF activities: value potential identification and baseline assessment.

As mentioned in the previous section, value is determined by the customer and companies must understand the customer in order to deliver product with superior value. An organization must learn and adjust their mental models to those of their customers as it would allow them to offer greater value. Imitating the mental model of the customer can serve as validation to the customer value offer of the firm. Woodruff (1997) suggest a process to do so which is pictured in

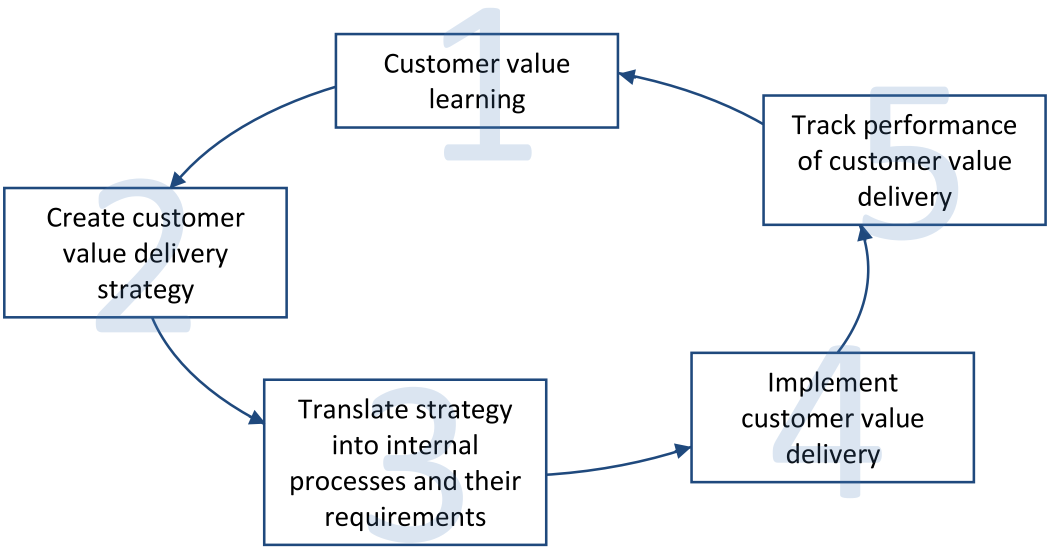

Figure 27. *Validating the customer-company value fit (Adapted from Woodruff 1997).*

In the first step, the company determines what customers value. Secondly, the company formulates a strategy out of it, which will captivate the interest of the customer. In the third step, the company identifies the internal organizational processes that work towards the value proposition of the offering. During the fourth step, as its name says it, the company puts the efforts to work.

Financial performance tracking is a regular practice among companies; step five suggests that they should do something similar with their customer value delivery. While the last may be difficult to quantify, the message is to raise awareness towards doing such tracking.

The previous image mentions the way to validate the value fit, but the need of a method to assess that value arises. According to Anderson et al. (1993), there are nine different methods to assess customer value. These are shown in Table 7.

Table 7. *Nine methods to assess customer value. (Adapted from Anderson el al. 1993)*

Method	Description
Internal engineering assessment	Scientist and/or engineers from inside the firms estimate the value of the product offering.
Field value-in-use assessment	Interviews are conducted with customers to determine an ample listing of cost elements linked to usage of the product offering compared to the incumbent product offering.
Indirect survey questions	In a field research study, respondents are asked what the effects of one or more changes in the product offering would have in their perception.
Focus group value assessment	In a focus group settings, participants are exposed to potential product offerings or concepts and are then asked what value it would bring to them or their businesses.
Direct survey questions	Similar to the previous, but instead of done in a focus group, it is done through field research survey.
Conjoint analysis	In a field research survey, respondents are asked to evaluate a set of potential product offerings in terms of their purchase preference, analyzing attributes as a group, not individually.
Benchmarks	In a field research survey, respondents are given the description of a product offering which is the industry standard. They are then asked how much more they would be willing to pay for additions in certain attributes.
Compositional approach	In a field research survey, respondents are urged to directly give the value of selected attributes represent to their firm. This is mostly for B2B analyses.
Importance ratings	In a field research survey, respondents are given a set of attributes of a product offering and are asked to rate them in order of importance according to their own needs

To this already thorough table one more assessment method can be added: customer value audit. Ulaga & Chacour (2001) depict it as a process were both company and customers are asked to evaluate their perception of value. This methods differs from the others in the sense that both entities, the firm and the customer, evaluate the product offering and express their perceived value in parallel, but separately. This can lead to interesting insights on the different perceptions and it can allow the firm to begin finding way how to fill the gap.

Figure 9 mentioned customer as a feedback generator as a suggested stakeholder in TF analysis. The ten aforementioned customer value assessment methods have the customer as the center point. In order to relate the previous assessment methods for technology forecast, they will be evaluated according to two measures.

The first one is the readiness of the product that would be needed. Customer value for TF cannot be directly assessed with all of the aforementioned techniques, as most of them require a ready to market prototype, which often in TF is not available. The second is the customer engagement needed for that assessment. Parting from the fact that TF products may still be theoretical or intangible, the degree to which the customer can engage in the process of valuing it is limited, as compared to ready-existing products. The analysis is shown in Figure 28.

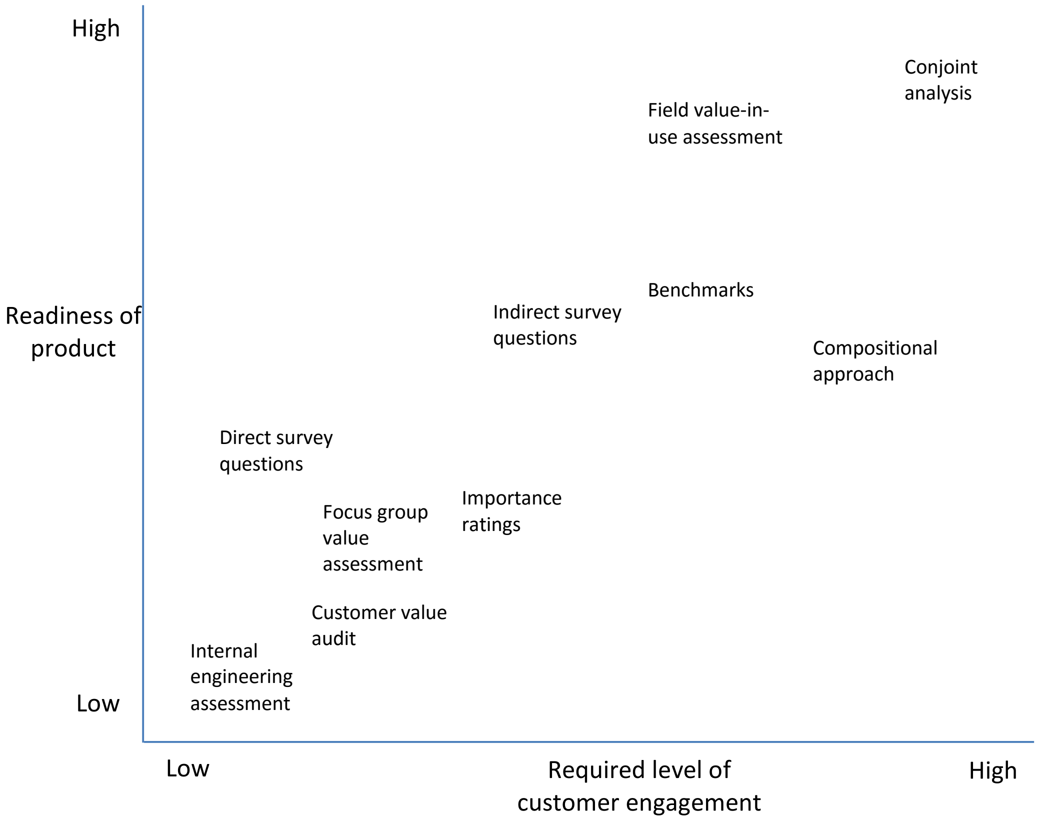

Figure 28. *Comparing assessment methods according to product readiness and needed customer engagement.*

Conjoint analysis deserves a special mention in here. According to Kotri (2006), conjoint analysis is one of the best methods for analyzing customer needs and often the most effective, as customers analyze several attributes of an offering in parallel, rather than individually. However, in order to relate value assessment to TF only the bottom left corner items will be considered because of the reasons explained previous to the image.

This leaves internal engineering assessment, focus group value assessment, direct survey question and importance ratings. Since focus group value assessment and direct survey questions are very similar methods, the latter will be dropped. Similarly, since customer value audit somewhat contains internal engineering assessment, the latter will not be considered either. As a result, there are three methods for performing customer value assessment in TF, which are:

- Focus group value assessment
- Importance ratings
- Customer value audit

In order to gain some perspective on the customer value assessment in terms of TF, the three main concepts presented during this section will be put together. This includes the selected elements from Figure 26 and Figure 28 (which were selected on the basis of suitability for TF) as well as the model from Figure 27. These elements come together in Figure 29.

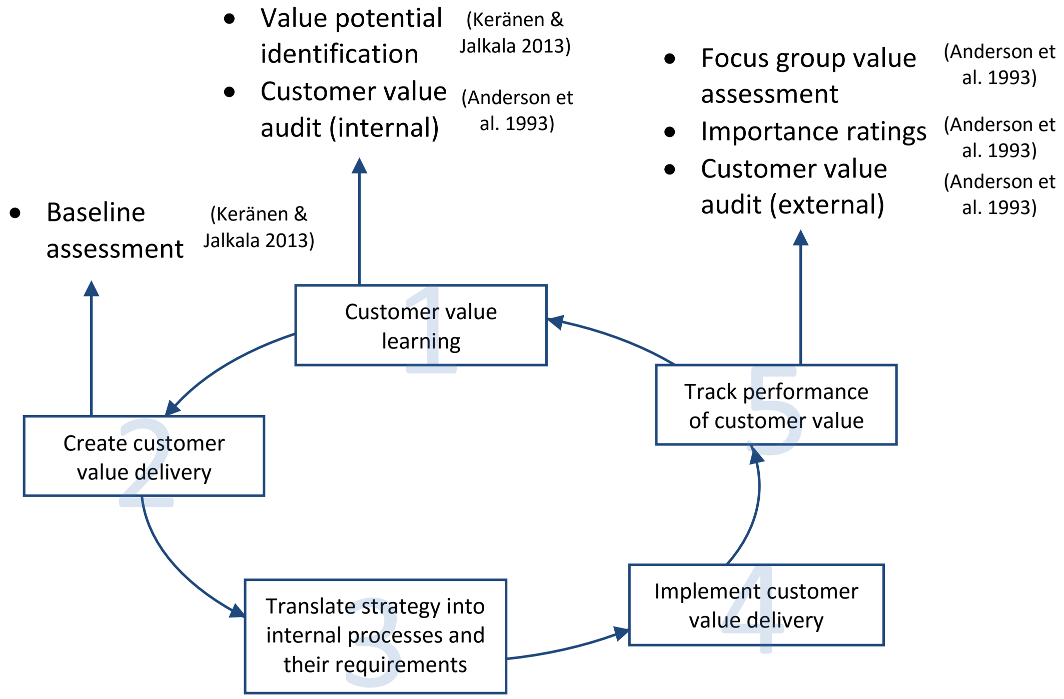

Figure 29. *A holistic value assessment model. (Adapted from Woodruff 1997).*

The previous model is a result of combining different elements of customer value and finding common elements which can were related to TF. Steps three and four are open to interpretation as to how to execute. The most important elements are step one, two and give, which is why they are backed up by concepts discussed throughout this section.

3.4 Customer value and the uncertain

Customer value literature focuses on current or nearly ready-to-market offerings. Authors do not discuss customer value in the plane of future potential innovations. This is partly what makes the translation of customer value to the realm of TF, which was done in the previous two sections, particularly challenging.

Möller (2006) asserts that the production of future value-creating innovations presumes multi-party collaboration manifested in business development networks. Despite of the importance of these processes, there is limited knowledge of the competences required in this domain. (Möller 2006) The statement of Möller is a guideline rather than a process. This statement is in line with what is portrayed in Figure 9, where suppliers and business partners are mentioned as important stakeholders in TF activities. Now more than ever their inclusion is important, as TF undertakings merge with customer value actions.

One more concept or model that can alleviate the difference between customer value in present and future offerings is the customer value determination process. Originally Woodruff (1997) describes it as a model designed to provide managers with answers to critical questions when learning about their customers. The model is depicted in Figure 30.

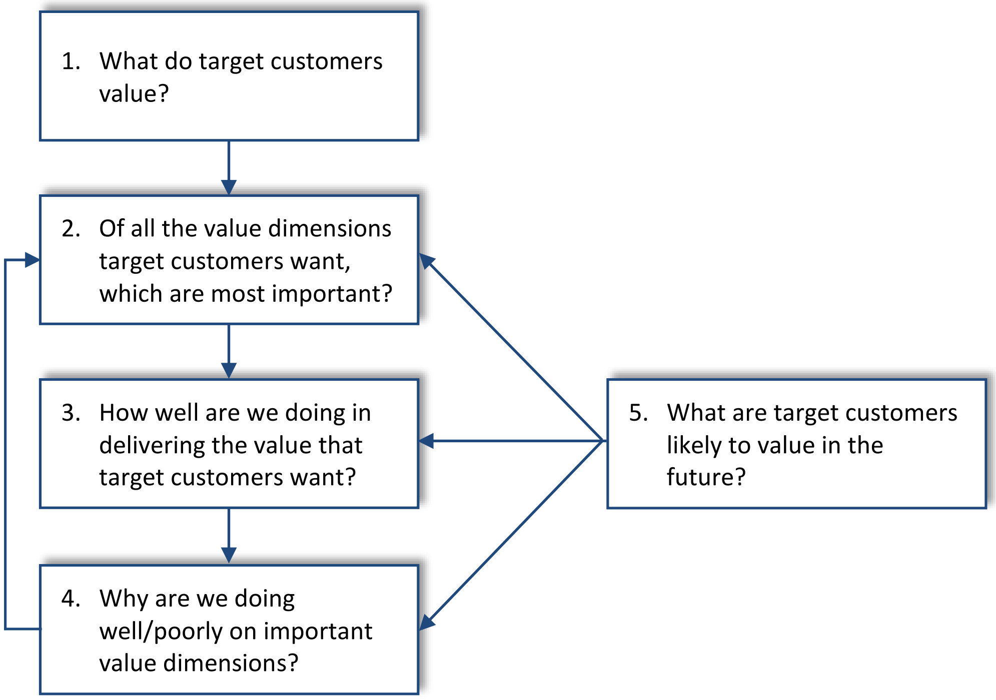

Figure 30. *Customer value determination process (Adapted from Woodruff 1997).*

In the first step any technique may be used (e.g. the ones mentioned in previous sections of this chapter) to acquire a more complete picture of the desired value of the customer.

Different customers may have an inclination towards different attributes in the same product. Step two raises awareness of this inclination, since companies cannot work on multiple dimensions of value at a time. In the third step, the company should evaluate if the value it envisioned is accepted by the customer. The fourth step attempts to do the necessary correction to the thirds step after having learned from experiences. The fifth step urges the company to be bold and make predictions in order to adapt more quickly to future changes of customer needs.

The previously depicted model cannot be put to work directly on future innovations. Some of the elements must be adapted, specially steps four and five. The reason being that in TF products are not available to the market and thus value cannot be evaluated against product usage. Figure 31 tailors this value determination model to the conditions of uncertainty inherent to TF activities.

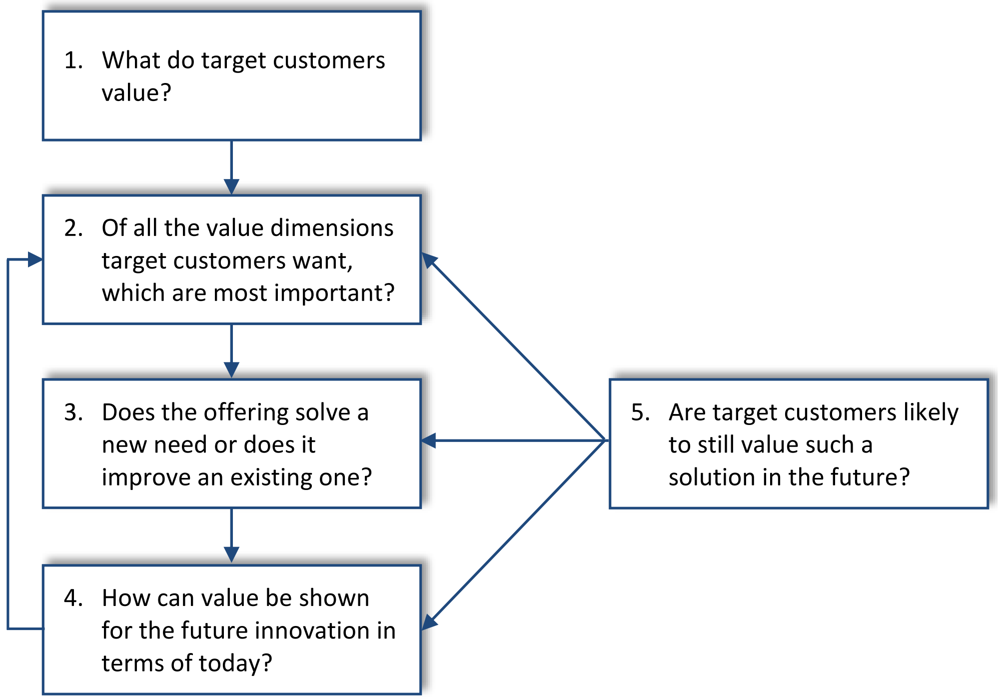

Figure 31. *Innovation value determination process.*

The first change that should be noticed is step three. The significance of this step is to identify whether the offering under TF solves an apparent new need or does it improve a new one.

Secondly, the offering under forecast may depend on futuristic technologies that may be widely used in present time or may not even exist. It is imperative to translate this offering into terms that average potential customers can understand, so that they can express their opinion and indicate the value they see in this potential offer.

Finally, the last step which oversees most of the process has to be adapted as well. Often technologies under forecast do not come to fruition because by the time they are able to become a reality, they are no longer needed i.e. the problem that made them necessary no longer exists, or an alternative took its place. This step works as a reminder to continually assess whether the potential offering will still bring the desired value to the customer.

To sum up, this chapter scrutinized customer value meticulously. Firstly, the importance of customer value was clarified, customer value was defined according to different authors and its components were analyzed, but most importantly, the initial approach to customer-centered TF was made. Section 3.2 proceeded to explain how customer value is measured, firstly how the customer itself intuitively does so, and secondly how companies execute it more comprehensively in order to offer superior value. The section that followed looked into assessing the customer value that has been offered, in order to improve the overall offering of the company. This section also showed a holistic value assessment model which was a result of thorough analysis. The innovation roadmap should then have some of these elements, which could effectively bridge the gap between TF and customer value. Finally, the present section brought to light how customer value needs to be modified in order to fit the realm of TF, if a new concept such as innovation roadmap is to be introduced, it should include elements that determine innovation value, such as the one from the last figure of this section.

4. THE WINTER TIRE AND THE INDUSTRY

4.1 Invention of the tire

The common day tire is an item that has been shaped through history. The life of the tire started in the 1840s, but came to prominence in the late 19th century. Figure 32 illustrates some of the most outstanding events in the history of the tire.

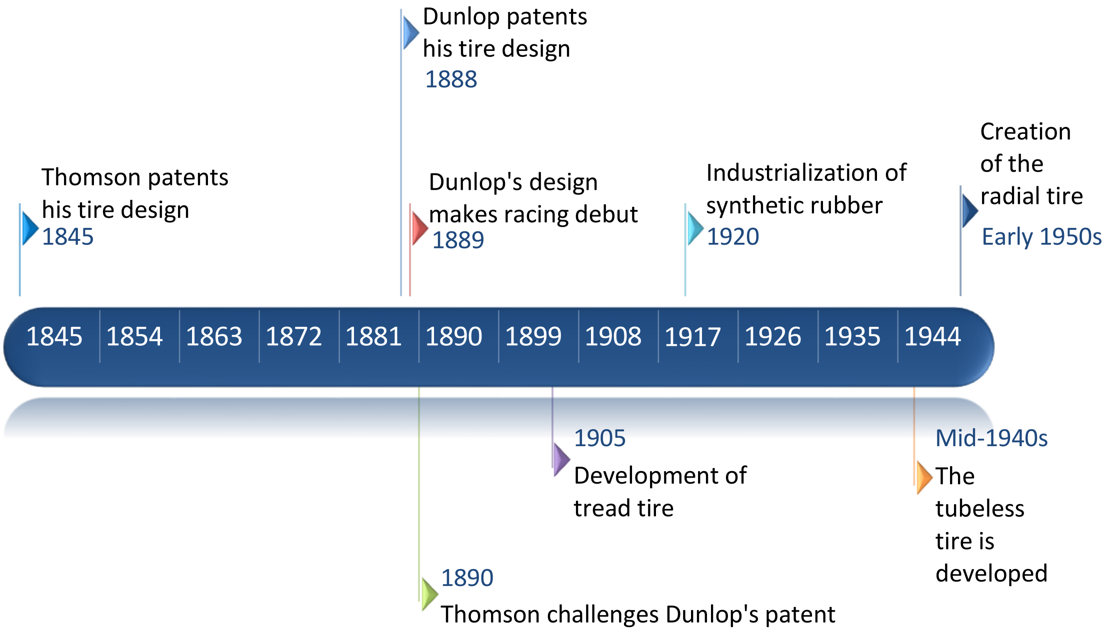

Figure 32. *A timeline of the tire invention and subsequent events.*

The earliest notion of a pneumatic tire was brought to life by Scottish inventor Robert William Thomson. According to Historic UK (Online) the Scot was only 23 years old when in 1845 when he applied for the patent for his pneumatic rubber tire or “aerial wheel”, as he referred to it. The purpose was to create a smoother and more comfortable ride by providing a cushion of air between the road and the vehicle itself. (Historic UK, Online)

Despite the demonstrable advantages, the pneumatic tire was largely ahead of its time; not only were there no cars at the time, but bicycles were barely starting to appear in towns and cities. The lack of demand, combined with the high production costs resulted into the tire remaining a mere curiosity. (Historic UK, Online) This is a rare case where the complementary technology, i.e. the tire, was ahead of the main technology, i.e. cars and bicycles. Thankfully, this would not signify the end for the pneumatic tire, not by far.

It was until 1888 that another Scotsman by the name of John Boyd Dunlop invented a tire of his own. According to Dunlop (Online), the Scotsman got the inspiration while watching his young son riding a tricycle on solid rubber tires over cobbled ground. He noticed the little boy could not go fast and the ride seemed rather uncomfortable. In order to solve this issue Dunlop began experimenting by wrapping wheels in thin rubber sheets, gluing them together and inflating them with a football pump. Eventually the tire was reborn. (Dunlop, Online) Figure 33 shows an early reproduction of this experiment.

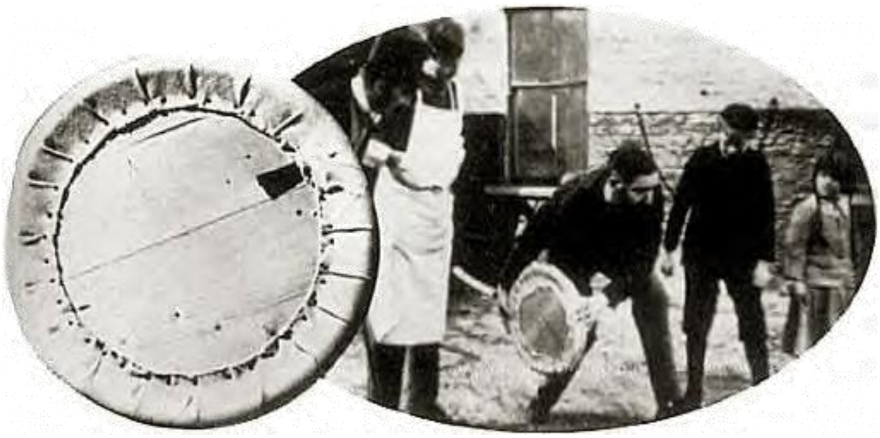

Figure 33. *An early reproduction of Dunlop's experiment (Dunlap, Online).*

Most importantly, the following year, the invention of Dunlop made its racing debut on bicycle competitions. The product was a success, the pneumatic tire enabled an unknown rider to beat stronger rivals in a series of races. (Dunlap, Online)

Dunlop patented his invention in 1888. The following year production began at a factory in Dublin. In 1890, the patent of Dunlop was challenged by Robert William Thomson. Fortunately, since the former had a different approach to producing tires (which was more expensive), Dunlop was able to continue manufacture of his own design. (Undiscovered Scotland, Online)

The tire slowly evolved to become what is known today. In 1905 the tread tire (the pattern visible, shown in Figure 34) which comes in direct contact with a road surface, was developed. 1920 saw the popularization of the automobile and the industrialization of synthetic rubber. Initially, the tire consisted of an inner tube, protected by an outer casing, in the mid-1940s the tubeless tire was developed, which soon would become the standard for most motorized vehicles. The radial tire was developed shortly after, in the early 1950s. (Hankook, Online) Other changes came afterwards, but these did not change the tire as it is, they are rather additional features or characteristics of specific models.

The tire has continued to evolve since the 1950s. Tires have become safer, more efficient, more eco-friendly, more reliable, more durable, however, the essence of it has remained unchanged.

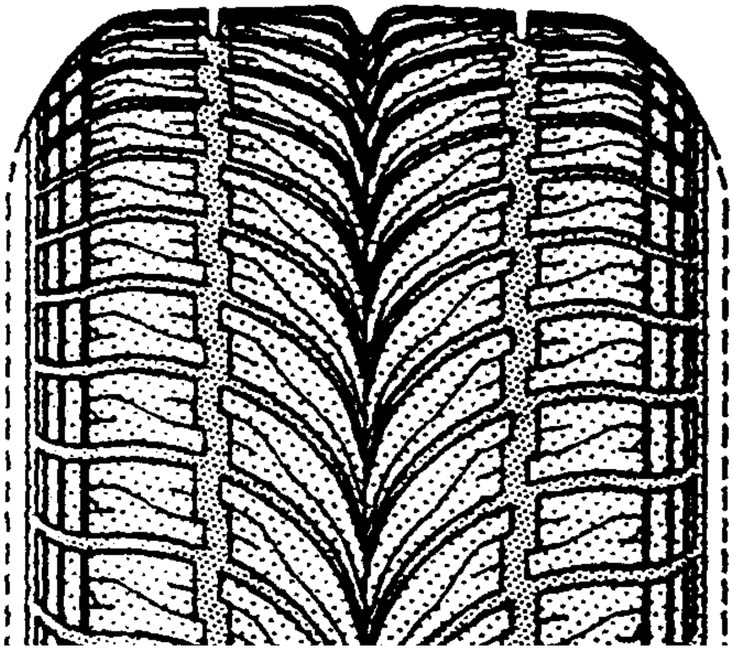

Figure 34. *An example of tire tread.*

Most, if not all of the tires used in modern day passenger vehicles are radial. Regardless of this fact, half of the tires used in construction fleet and similar large machinery are still bias-ply, not radial, though the percentage of the latter continues to increase (2004). In the case of transportation trucks, both continue to be used (RecStuff.com, Online). The difference between the two will be explained in the next section.

4.2 The tire

Opposed to what could be assumed, a tire is a tremendously complex technical product with a vast number of components. Though tires may often be overlooked within the automobile as a whole, they are the only point of contact between the car and the road. In order to fully take advantage of the properties of a car such fast acceleration, aggressive cornering, reduced braking distance and improved fuel economy, among many others, a high quality tire must be paired up with it.

Up until the late 1940s, all pneumatic tires were bias-ply. Once its radial counterpart was introduced, the world slowly began shifting towards it. The main difference between bias-ply and radial tires is the orientation of the plies. Plies are layers of relatively inextensible cord embedded in the rubber to hold its shape, preventing the rubber from stretching due to internal pressure (WheelPros, Online).

A bias-ply tire utilize plies that extend diagonally in angles of 30 to 40 degrees. Successive plies are placed at opposing angles forming crisscross patterns on which the tread is then applied. (Wheel Pros, Online) The construction of a bias-ply tire can be seen in Figure 35.

Figure 35. *Construction of a bias-ply tire.*

A radial tire utilizes a ply which is perpendicular to the rolling direction, i.e. cords that extend radially from the center of the wheel. Additionally, it has stabilizer belts between the radial ply and the tread. These can be made of cord or steel. (WheelPros, Online) An example of a radial tire is shown in Figure 36.

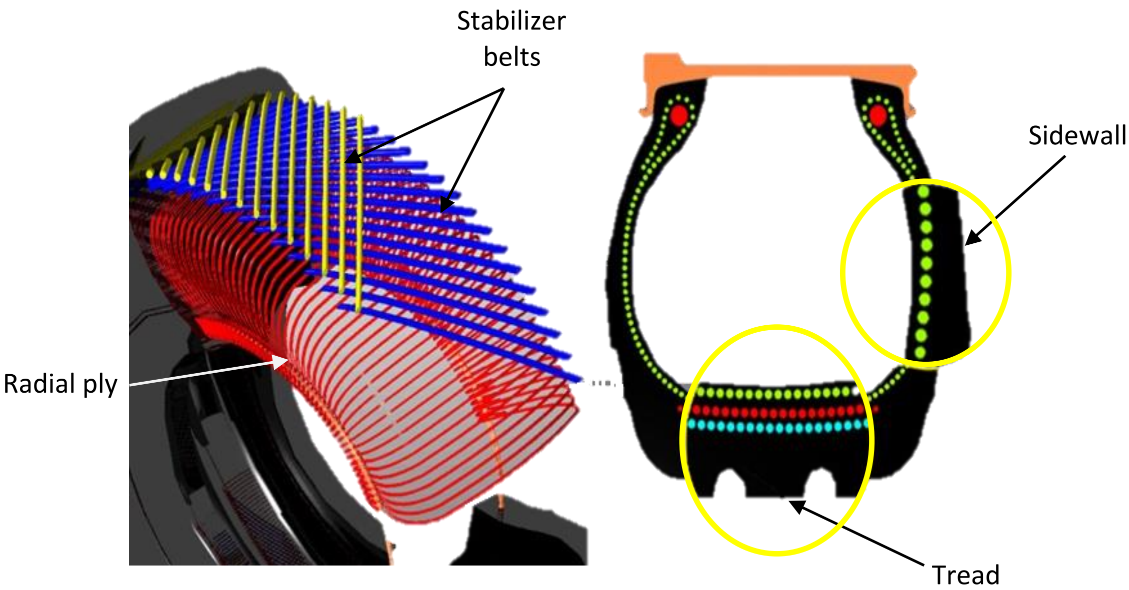

Figure 36. *Construction of a radial tire.*

Bias-ply tires have one main benefit over radial tires, their lower cost. On the other hand, radial tires have a longer life, requiring less change and overall reducing the total cost of ownership (TCO). All and all, the radial tire has more benefits over the early bias-ply. Some of those benefits can be seen in Table 8.

Table 8. Benefits of the radial tire over the bias-ply as mentioned by different sites.

Attribute	WheelPros (Online)	Michelin (Online)	RecStuff (Online)
Longer life	✓	✓	✓
More resistance to puncture and tears	✓		
Better traction	✓	✓	
Better handling	✓		
Better fuel economy	✓	✓	
More comfortable ride	✓	✓	
Wider footprint (Contact patch)		✓	✓
Runs at cooler temperature			✓

The radial tire has a more solid construction which gives it better handling and longer life. Because of the steel belts, the radial tire is more resistant to punctures. The radial design of the plies avoid them from rubbing against each other, reducing rolling resistance and improving fuel economy. Since the radial tire does not have several layers of plies like the bias-ply, there is less friction and thus it heats less.

As mentioned, a tire is composed of many elements. According to Goodyear[1] (Online) a tire has the following parts:

- Tread
- Beads
- Sidewall
- Ply
- Belt
- Shoulder
- Groove

The previous can be identified in every tire. Some other websites consider the following component as well:

- Inner liner (My Certified Service, Online)
- Optional cap plies (Nice, Online)

The inner liner is simply the inner most layer of a tire, all tires have them, some authors or websites simply do not choose to mention it. Cap plies are optional elements which may not be present in all tires.

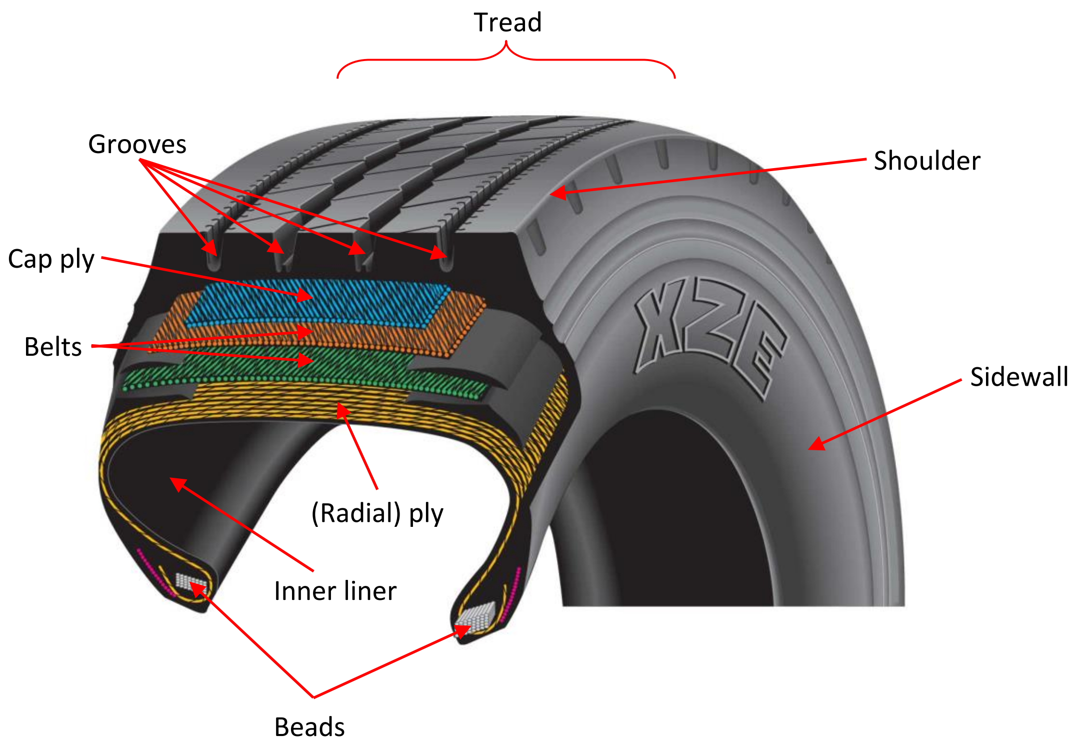

Figure 37. *The parts of a tire.*

The tread is the soft area of the tire which makes contact with the road. It provides both cushioning and grip, and its design and compound dictate the most important performance features of a tire. The bead is an element made from braided steel coated in rubber. The purpose of the bead is to create an airtight seal between the tire and the rim. The sidewall is the area of extra thick rubber which runs from the bead to the tread. Its function is to give the tire lateral stability. It is also where the manufacturer information can be found. The plies are the layers of fabric which make up the tire skeleton, they are typically fiber cords which are woven together and coated with rubber. The belts are woven sheets of steel wire coated in rubber placed between the ply and the tread with the purpose of reinforcing strength and providing rigidity. The shoulder is a small beveled edge where the tread meets the sidewall. Its design and construction play an important role in how the tires takes corners. The grooves are channels that separate the tread blocks and allow the tire to disperse water and mud. (Goodyear[1], Online)

The inner liner is the innermost layer of a tubeless that prevents air from penetrating the tire (Certified Service, Online). Some tires may have cap plies, an extra layer or two of polyester to help hold everything in place. These are not common on all tires; they are most common on tires meant for higher speed performance. (Nice, Online) Now that the common tire is a familiar item, the winter tire, which is the center of the case of this thesis, can be introduced.

4.3 The winter tire

While the first tire was invented in 1845 and they came to prominence in the 1890s, it would not be until 45 or so years later that winter tires (also referred to as snow tires) would come to the scene. The first winter tire was developed in Finland, where the harsh weather conditions made the need of an adequate tire clear. As told by Nokian Tyres[1] (Online) the first winter tire was manufactured in 1934 and it was developed for trucks and trailers. This first winter tire was developed with winter in mind, it had a completely new kind of tread pattern, as its grooves were completely transverse to provide teeth-like grip in the snow and mud. (Nokian Tyres[1], Online) This tire can be seen in Figure 38.

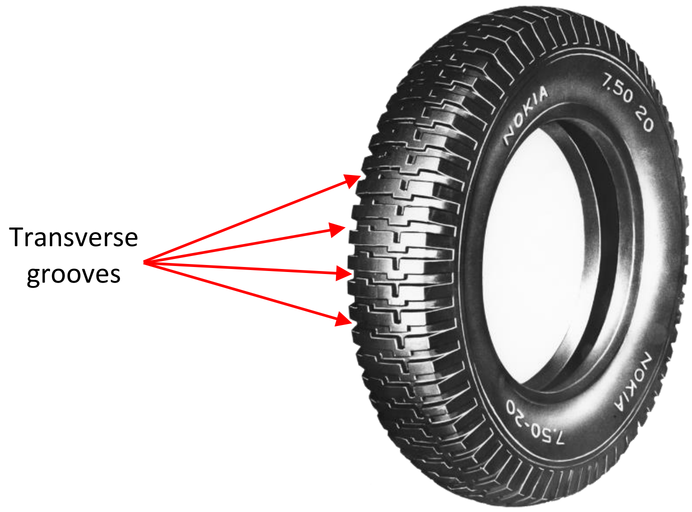

Figure 38. *The first winter tire (Nokian Tyres[1], Online).*

Back in the 1930s road conditions were poor, yet cars were driven all year long. As the 1930s saw an increase in the number of passenger cars, it became apparent that these required new types of tires as well. In 1936 the first tires for passenger cars were developed. (Nokian Tyres[1], Online)

According to Tyremen[1] (Online), winter tires are not only required in snowy conditions. Winter tires are needed in temperatures below 7°C where the braking distance under wet conditions can be compromised. Winter tires have several elements that differ them from regular summer tires. As stated by Bridgestone[1] (Online), in extreme cold temperatures, the tread rubber of a summer tire stiffens and becomes unable to provide proper traction. To combat these issues, tread rubber compounds of winter tires are designed to remain flexible, allowing the tire to grip to road better. Visually speaking, winter tires have deeper tread depths and unique patterns which reduce snow buildup and provide better traction on snow. The tread patters are designed to channel snow and slush as well as well as to expel water. (Bridgestone[1], Online) One more unique characteristic of winter tires are sipes. These are tiny slits in the tread that provide traction on ice (Bridgestone[1], online). A picture of a winter tire demonstrating these specific features is shown in Figure 39.

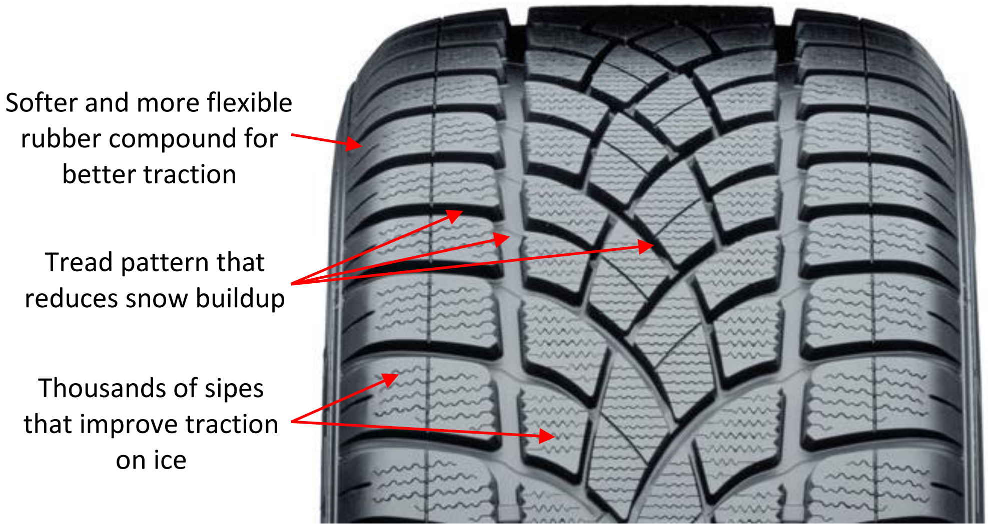

Figure 39. *The specific attributes of a winter tire.*

Finally, one more characteristic of a winter tire are studs. Studs are small metal pieces that project from the surface on the tire to make contact and improve traction, they are usually made from tungsten carbide (an extremely hard metal) and protrude around 1.2-1.5 mm from the tire (Pavement Interactive, Online). Nevertheless, not all winter tires are studded. Figure 40 shows an example of a non-studded and a studded tire.

Figure 40. *Example of a non-studded and a studded winter tire.*

Each tire offers particular benefits. According to Nokian Tyres[2] (Online) studded tires work better on icy roads, while non-studded are suitable for snowy roads. Similarly, studded tires outperform non-studded in wet ice and hard-packed snow. On the other hand, due to laws and regulations, non-studded tires can be mounted earlier on into fall, which makes them particularly useful for unpredictable conditions during the fall season. The same applies during spring. Finally, non-studded tires offer one noticeable benefit over a studded product; they are quieter on bare roads. (Nokian Tyres[2], Online)

Now that the specifics of the winter tire have been described, the next section takes a quick look at the industry.

4.4 The industry and the market

Though somewhat obvious, only a few countries in the world require the use of winter tires to get through the snowy season. Winter tires mostly in European countries, outside of these, winter tires are also used in US, Canada and Japan. Table 9 shows a complete list of countries where winter tires are used, which gives an idea of the geographical expansion of the industry.

Table 9. *A list of countries which use winter tires and their regulations (Adapted from AA [Online] & Tyremen[2] [Online]).*

Country	Regulation
Andorra	Recommended
Austria	Mandatory
Bulgaria	Recommended
Canada	Mandatory (Certain territories) Recommenced (Certain territories
Croatia	Mandatory
Czech Republic	Mandatory
Estonia	Mandatory
Finland	Mandatory
France	Recommended (Alps region)
Germany	Mandatory
Hungary	Recommended
Italy	Recommended
Japan	Mandatory
Lithuania	Mandatory
Luxembourg	Recommended
Latvia	Mandatory
Norway	Mandatory
Poland	Recommended
Russia	Mandatory
Serbia	Recommended
Slovakia	Mandatory
Slovenia	Mandatory
Spain	Recommended (Northern)
US	Mandatory (Certain states)
Sweden	Mandatory
Switzerland	Recommended

At first glance, the market for winter tires is small, if the number of countries in the Table is considered against the rest of the world. Additionally, winter tires are only used for a certain period of the year, meaning vehicles that run on winter tires equally need summer tires for the rest of the year, but this should be put into numbers in order to gain a better perspective. The global demand for tires during 2015 was an estimated 1.72 billion units (PRweb, Online). In the Nordic countries, the yearly sales of winter tires reach an estimated 6 million units. In the rest of Europe (including Russia) that volume racks up a staggering 85 million units. This number in US and Canada totals 16 million units. (Nokian Tyres3, Online) The yearly sales of winter tires in Japan come up to 25 million units. These sales numbers can be seen in Figure 41

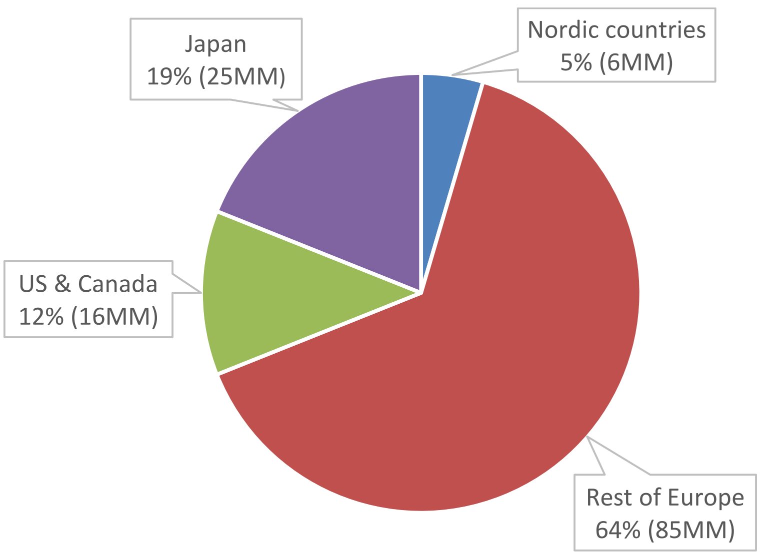

Figure 41. *Yearly estimated sales of winter tires in units per area.*

The total yearly sales of winter tires come to an estimated total of 132 million units. As a part of the grand total estimate of 1.72 billion units sold, winter tires represent roughly 7.6% of the total. While this segment could seem small in perspective, it is in fact a very attractive one. It is indeed so substantial, that many different players battle for a share of the market. Figure 42 shows some of the most salient manufacturers of winter tires.

Figure 42. *Some of the biggest names in the winter tire industry.*

Most of these companies have a strong presence in the regular summer tire market, where the most money is to be made. Other companies have taken a special focus in the winter tire sector, some have specialized in heavy duty tires. Nevertheless they all have a considerable stake in the winter tire industry. The fact that so many recognized names compete for a piece of a relatively “small” segment highlights the need of innovation as a differentiator, which is the purpose behind the case portrayed as a part of this thesis.

4.5 Innovations in the tire

The objective of this section is to discuss some of the most outstanding tire innovations that have occurred after the milestones mentioned in Sections 4.1, 4.2 and 4.3, i.e. events such as the invention of the tubeless tire, the radial tire and the winter tire itself. The reason for this is to set the tone as to how innovation has happened in the industry in recent years and how the case of this thesis is an attempt to go one step beyond.

In the recent past and current day, most tire innovations happen within two specific dimensions: design and chemistry. Through experience and expertise, developers learn, and as a result are capable of creating tires which can for instance, reduce rolling resistance and improve fuel economy while not compromising performance on cornering and braking distance. Through improved designs, researchers are able to create for example, a tire which reduces hydroplaning (the loss of traction created when a layer of water builds between the wheels and the surface, and as a result prevents the vehicle from responding to control inputs) and at the same time operates at a lower temperature.

The other criterion of common innovation is the change of rubber composites. Through complex chemistry that formulates new rubber compounds, tires can guarantee maximum traction, even in the harshest conditions. The development of new greener compounds allows manufacturers to reduce the carbon footprint of the product and reduce the impact on the environment. Improved mixtures can extended the useful life while similarly increasing its performance attributes. While these innovations can be considered as significant leaps forward, most of these changes happen within a narrow spectrum.

One innovative product that stayed in the spotlight for a short period is the run flat tire (also run-flat). According to Autoguide (Online), they have been around since the 1990s. According to Pirelli (Online), run flats provide greater control of the car in emergency conditions and grant the user with the possibility to continue driving safely even during a rapid loss of pressure. They allow the driver to retain mobility in the event of a puncture, avoiding the hassle of putting on the spare right away. When punctured, run flats can continue to run for distances of up to 80km at speeds of up to 80km/h. (Pirelli, Online)

There are two types of run flat tires, self-supporting and auxiliary supported. The first kind have stiffer and tougher rubber on the sidewalls, which can temporarily carry the weight of the vehicle under low tire pressure. Auxiliary supported tires depend on a different principle, rather than tougher materials, they are attached to a special rim which has a steel support ring that is attached to the wheel and can support the weight of the vehicle. (Haj-Assaad, 2012) Both tires are shown in Figure 43.

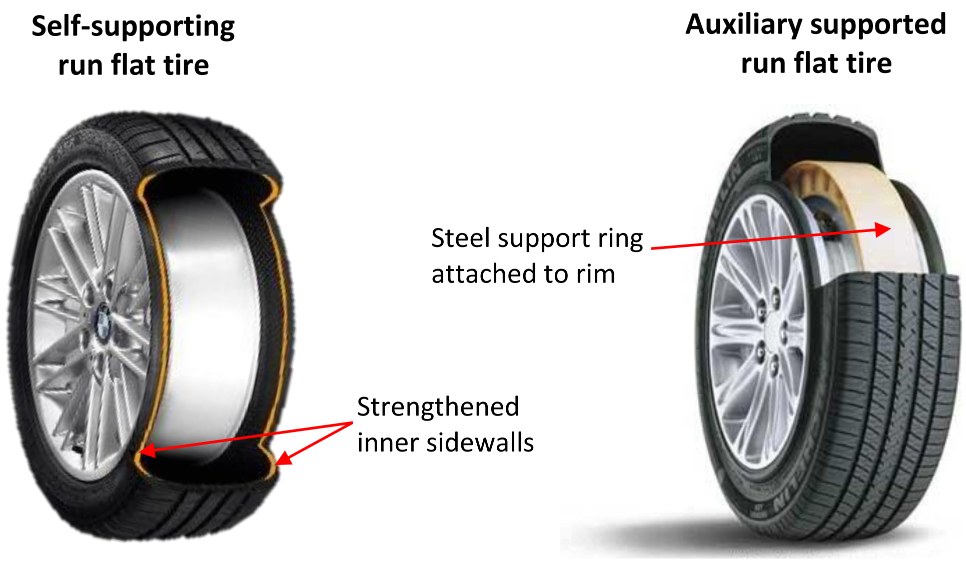

Figure 43. *The difference between a self-supporting and an auxiliary supported run flat.*

With all the benefits mentioned in the previous page, it would seem logical to assume that run flats are a favorite among drivers, but the reality is far from it, the reason is that they have several drawbacks. According to Haj-Assaad (2012) run flats are on average one third more expensive than regular tires. Additionally, since they are heavier and thicker they have an impact on fuel economy, reducing it by 1-2%. Furthermore, when they are indeed punctured, they are not so easy to repair. (Haj-Assaad 2012) Pirelli (Online) adds one more item to this list of shortcomings by emphasizing how run flat tires are developed based on specifications of the vehicles on which they will be mounted. They are calibrated to the specific attributes of the car and they require a tire pressure monitoring system. These TPMS systems are automated. (Pirelli, Online) Run flats continues to be available in the market, but their adoption has been minuscule.

Another innovation worthy of mention is the self-inflating tire. According to Goodyear[2] (Online), these tires monitor pressures and automatically inflate the tires using a regulator (sensor) and a tube. All the components of this system are fully contained within the tire. The benefits lie ahead of just the fact that eliminates the need for the driver to check and manually inflate the tires. A properly inflated tire saves fuel and extends its lifetime. (Goodyear[2], Online) These tires are not yet available to the consumer as they are still in developmental stages.

Perhaps the biggest breakthrough since the invention of the tire itself, is the introduction of non-pneumatic tires (NPT), also called airless tires. As described by Bridgestone[2]

(Online), NPTs do not rely on air for cushion, instead they feature unique spoke structures designed to support the weight of the vehicle. Some of the obvious benefits of NPTs are not having to deal with flat tires and saving the need of carrying a spare tire as a consequence of it. Furthermore, because of its design, it is possible to employ sustainable recyclable materials in the manufacture of an NPT, contributing to the efficient use of resources. (Bridgestone[2], Online) Additionally, according to Branman (2015), the design of NPTs reduces the construction process from eight stages to only four, meaning these types of tires carry a smaller carbon footprint right from the very start. Finally, one more benefit of NPTs over their pneumatic counterpart is reusability, when the rubber part of an NPT wears out, a new one can be fitted (Shankland 2014). Thought it is still early to speculate, NPTs appear to have real potential in the future market.

NPTs have been around since 2005 or so, which means they are still in early development. Current prototypes of NPTs have been successfully put to the test for different uses. Some of them have been used in military vehicles, others have been used for loaders and there are even products aimed at passenger cars or specially developed for prototype vehicles. (Shankland 2014). Some examples of NPTs can be seen in Figure 44.

Figure 44. *Different NPT prototypes tailored for different needs.*

Although NPTs have plenty of benefits, they also have many drawbacks, which need to be solved before they can begin to make their way to the market. As Grabianowsky (Online) points out, current prototypes still have vibration issues and have top speeds of around 80km/h. Airless tires are prone to fatigue and overheating at high speeds, which compromises its integrity, newer prototypes are pushing this limitation, though it is still long before NPTs can compete toe to toe with a pneumatic tire. These are just technical limitations which will most likely disappear as NPTs continue to be pushed forward. Nevertheless, airless tires have one major hurdle. Even though its manufacturing process is simpler than that of a regular tire, mass production would require a major overhaul of current manufacturing facilities for any producer, something that, while not insurmountable, would present a sizeable challenge.

The first of these innovations, run flats, can be put under the microscope in an attempt to explain its lack of success. Though perhaps technically superior to common tires in many aspects, its weaknesses in key areas far outweigh the benefits. It can be speculated how such a tire could have been forecasted and later conceived as a technological wonder. For a technology to be adopted by the users, it has to be superior in the aspects the customer actually values.

The model shown in Figure 29 offers a way to assess customer value from before a product is conceived to after customer adoption. It can be argued, that in the case of run flats, Steps 1 & 2 where neglected. Steps 3 & 4 were most likely executed with a technology first approach, and only afterwards customer value was assessed (Step 5). This assessment is show in Figure 45.

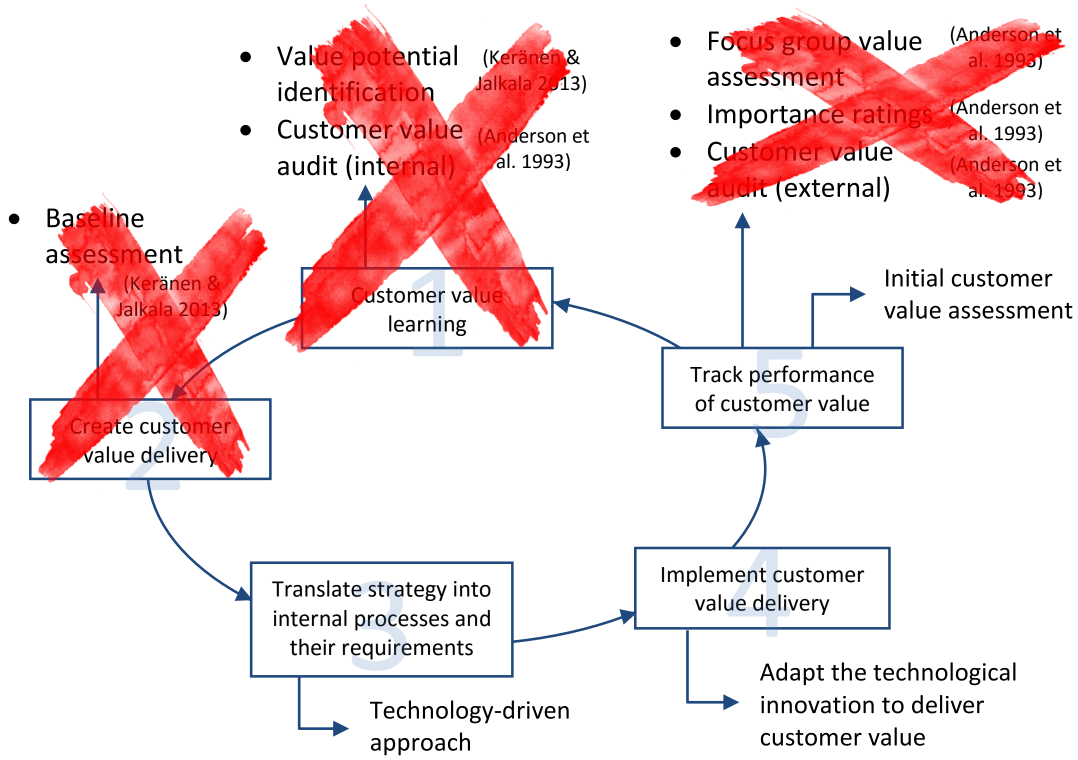

Figure 45. *The value assessment model applied to run flats.*

The image above shows how the process begins with the development of technology, and not with the assessment of customer value. The end result is a lack of fit between technology and value. This is once again an example of how a technology developed without all of the needs and desires of the customer as the pivoting point can fall short of delivering true customer value and, as a result fall short of success. As mentioned before the figure, this assessment in merely a speculation, tire manufacturers could have had ulterior motives or a different agenda when run flat tires where forecasted, designed and brought to life. In order to avoid an excess of speculations, the corresponding assessment for NPTs will not be performed, especially since NPTs are still only in the developmental stage.

In retrospective, this chapter covered the tire. The first section narrated the history of the invention of the tire and subsequent important events which transformed the tire to what it is known today. Afterwards, the tire, its components and inner workings were introduced, to give the lecturer an understanding of the product. After being familiarized, the winter tire, the focal point of the case of this thesis, was introduced and the special attributes that differentiate it from regular tires were pointed out. The previous section talked about the winter tire industry, the countries where winter tires are employed, their sales contribution and most prominent manufacturers were told. Finally, this section mentioned some of the most outstanding innovations in the tire field, but most importantly, based on a tool introduced in the previous chapter, it explained why possibly one of them did not amount to be a major market success.

5. CASE CONCEPT TIRE AND THE INEXPERIENCED TEAM

5.1 The idea and the need behind the project

The project was born out of an area of opportunity and a need identified by the case company. Most tire manufacturers invest heavily into future innovations and prototypes. There are years and considerable amounts of money put into such efforts and many times some inventions do not see the light of day. While researchers and developers work around the clock in order to deliver the next great tire year after year, some players in the industry experiment beyond the limitations of current technology and venture in the realm of what seems to defy presumptions of the tire and the industry.

It was in this wavelength that the case company decided to do a project looking forward to the tire of the future and, to be more specific, the winter tire of the future. The purpose of this project was be to look ahead of what tires currently are and do, and think of what a tire could be in the mid- and long-term future. The initial vision for the project, according to the company was to "create new groundbreaking ideas for future concept tires". To elaborate on the previous, the company had defined that the selected team should…

> *"... create a new innovative concept tire for us, with the main focus being on winter tires. How do you see the future of the black round rubber? What possibilities are there for future tire form factors or functionalities? The team should also find ways to promote the concept tire. This innovative project lets you, team members, set your mind free".*

The company gave the project team the liberty, or rather the instructions to do truly out-of-the-box thinking. This meant the team had to investigate technologies outside the tire industry and combine them to create something potentially revolutionary. The project team was to function as a think-tank, a group of people instructed to develop as many future tire ideas as possible. However, these ideas were to be developed on a conceptual level, some level of validation on the feasibility of each idea was a requirement, but the team was instructed to stay away from any notion regarding the building of demos or prototypes or go too far as to how such tire could be manufactured and brought to life.

For the case company it was important, although not a requirement, that the team members involved in the project were not very knowledgeable on tires nor the industry. The belief behind such stipulation was that inexperienced individuals could bring a fresh new take on an old product which experts could not. The company believed their developers could be limited in their thinking due to their experience, which would stop them from reasoning outside of the boundaries of their everyday work, which in turn meant that their most innovative thinking would render results not far from the present day tire. This limitation would not be the case with the project team. The argument behind it is explained through a Venn diagram in Figure 46.

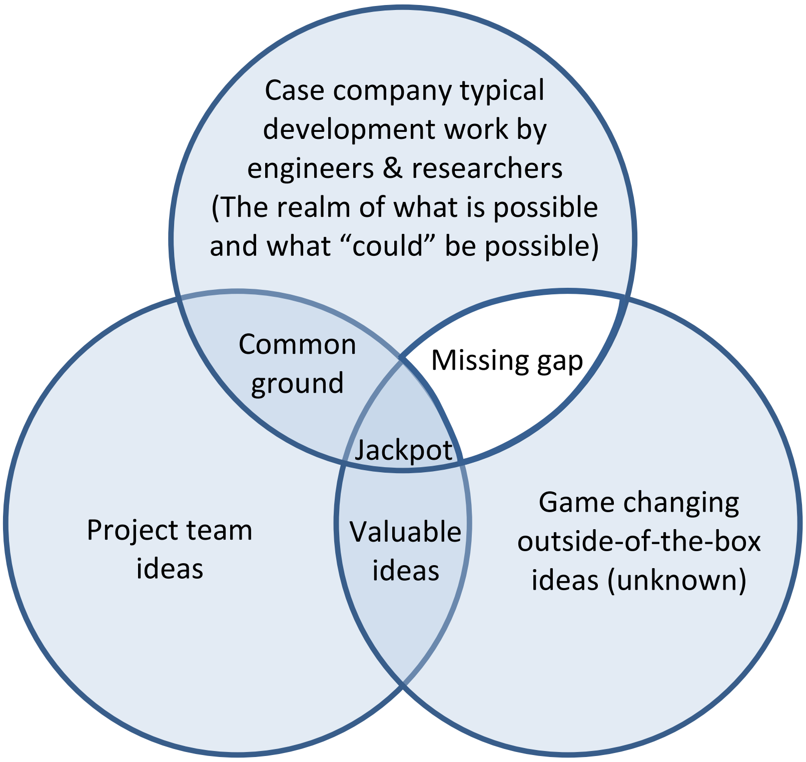

Figure 46. *Expert developers, inexperienced team members and the role they played together.*

Of course the team could not handle everything on their own, or better said, even getting started became a challenge. Getting involved with tires meant that the team members had to become acquainted with the product. It was at this point where the company came into their primary role. The company had the task of introducing the team to the basics of the tire and the tire industry. The company had to give the team a solid understanding of how a tire is made and how all of its components work. Furthermore, the company had to show the team what innovations had happened in the field and the direction in which some of the future trends were going. What was yet more important, once the project got underway, the company was periodically in contact with the team, giving some early feedback on ideas, so that the team knew if any given topic was worth pursuing or whether it had already been done or unsuccessfully tried in the industry.

Due to the nature of the project, there was always the possibility that some ideas could be deemed impractical, improbable, of little value or simply downright silly. Hence the indication to the team to develop as many ideas as possible. The true value of the project resided in delivering a large set of concept ideas which would then be passed on to the developers and engineers of the case company for analysis. The objective being not necessarily the development of one of them, but perhaps some elements from an idea could be utilized, elements of different ideas could be combined or some ideas could trigger new innovative ideas from the engineers. An example of how the case results would be received by the case company and its experts is shown in Figure 47.

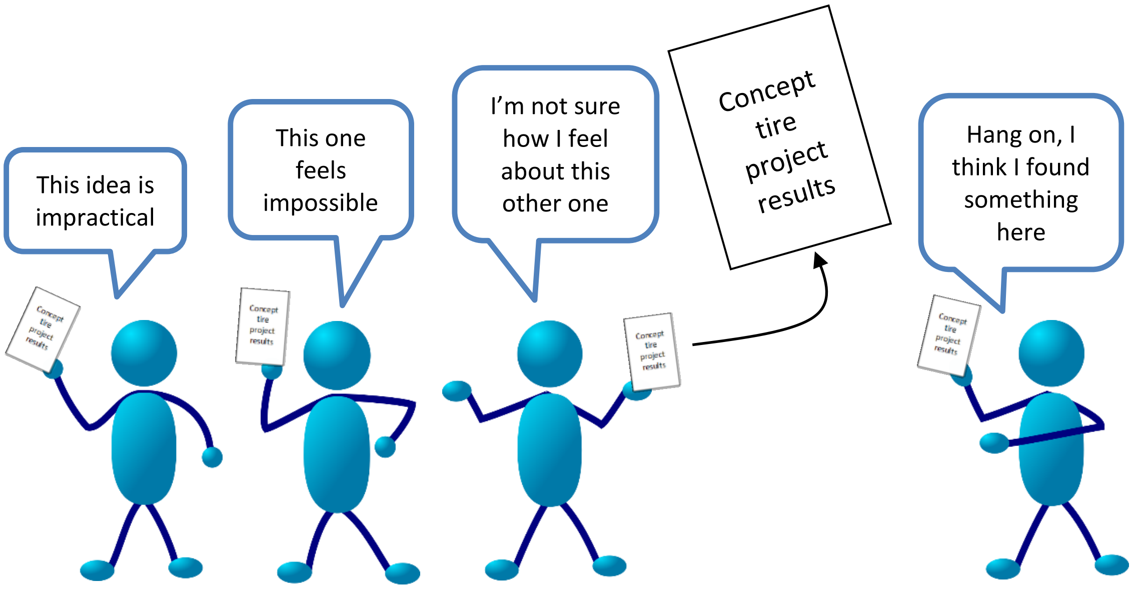

Figure 47. *Potential use of the case results by the case company.*

The case company believed the project team could deliver that extra, which could freshen the view of their research staff and spark future innovation. In other words, the objective of this project was to bring the best of two worlds together, the boldness of the inexperienced and the knowledge of the experts. This project defied what was discussed during the literature review of TF in Chapter 2, which is how technology exploration is driven mainly by experts. In this particular instance, the main actors behind the project were inexperienced individuals, while experts were employed as a secondary asset. This way of work will be further discussed in Section 5.3.

5.2 The inexperienced team

One of the main reasons, if not the most important, why this project broke the mold when it comes to technology forecasting, is the fact that all of the team members had no previous experience in tires. It was essential to find the right set of expertise among these team members. The team would need complimenting skillsets, students that could push each other and come up with revolutionary ideas as a result of the mashup of different disciplines. The project case team was formed by three members, all students of TUT. They were:

- A student of M.Sc. in Materials Engineering

- A student of M.Sc. in Nanotechnology & Biomaterials
- A student of M.Sc. in Business & Technology

The different areas of expertise meant that this case could explore diverse salients in their work towards innovation. Having a student of material engineering meant that the team could give a realistic start point and slowly progress towards the far-fetched. A student of nanotechnology & biomaterials could bring knowledge on some of the newest innovations in a field that has become increasingly important in recent years. Finally, a student of Business & Technology could, among other things, steer the team away from a uniquely technological approach and into a customer oriented one.

The project team was initially composed of 5 members, two of which dropped out soon after the project began. Seeing that the expertise and skillset of the remaining members was complementary, it was decided it that it would not be necessary to enlist more people on the team.

5.3 Development of the project

The present section as well as the following section of this chapter will cover some of the work performed during the case. In order to protect the interests of the project partner, limited information is provided in regards to the ideas and overall project results. This section shows some of the work performed during the project while the next section presents some of the final results. Selected ideas are presented and discussed in rather general terms. As it has been done throughout this thesis, no sensible information of the case company is revealed.

While the case started through a Demola kick-off event, as mentioned in Section 1.4, the actual work with the project partner began on October 1st 2014, when the three main parties of the project had the initial meeting. The purpose of said meeting, was to give a quick introduction to the Demola model and for the project partner to state its intentions and expectations, which were both depicted in the previous section.

Soon afterwards, the group became an iterative think-tank. The team developed a process of constant research and brainstorming with the purpose of combining technologies, concepts, devices and more with the ultimate goal of having it all come together as concept tire ideas. Once the project got underway, the three involved parties met roughly on a biweekly basis. During those meetings the team presented their latest ideas and presented their questions and doubts. The project partner gave feedback and offered answers to the team and sometimes even small suggestions. In any case, it is important to notice the project partner never steered the group into a particular direction; it simply offered advice. The team was always responsible for the project in its entirety.

At the beginning of the project, there were three main sources for brainstorming and ideation: a factory visit, the mentoring of the project partner during the biweekly meetings, and the firstly and most importantly, research on the internet and written media. It was Early into the project when the team had the opportunity to visit the manufacturing facilities of the case company (October 23rd 2014). The team was given the tour of the factory and was able to witness how tires are made from beginning to end.

It was important to understand the tire inside out, on a basic level at least, but at the same time, the team had a daunting revelation. Tire manufacturing facilities are a "perfect functioning entity" working in unison and harmony, changing even the smallest element in a tire could require the complete overhaul of the manufacturing process, and thus the manufacturing facilities. In the end, this epiphany was seen as a relief, since even the smallest change carried potentially drastic consequences with it, the team realized it should go all out and aim for even the most far-fetched ideas.

At this point, it is worth bringing up one particular concept from the literature review of Chapter 2, the Delphi method. In Section 2.5 and mostly in Figure 14 the Delphi method is explained when it is applied to TF (as mentioned earlier, the Delphi method can be used for almost any purpose where a group of people is utilized). The starting point of this methodology is a moderator and a panel of expert who are more knowledgeable on the technology being forecasted. The process is put underway when the panelists make their own predictions in an open unstructured way. After a minimum of 4 rounds, which include statistical analyses, anonymous exchange of opinions and rebuttal/agreement of statements, the final report is prepared, where final argument in case of a lack of consensus are included. Thoroughly during the entire Delphi process, expert panelists make full use of their experience and expertise in the field.

When looking at the entire picture, the whole process of the case can be seen as a spin of the typical Delphi process. The inexperienced project team takes the role of the panelists and the moderator is replaced by the project partner, the expert on the field. The project team still keeps the power on the decision of the project and the representative, rather than moderating, offers guidance and mentorship, and lets the team carry on the project. This analogy can be seen in detail in Figure 48.

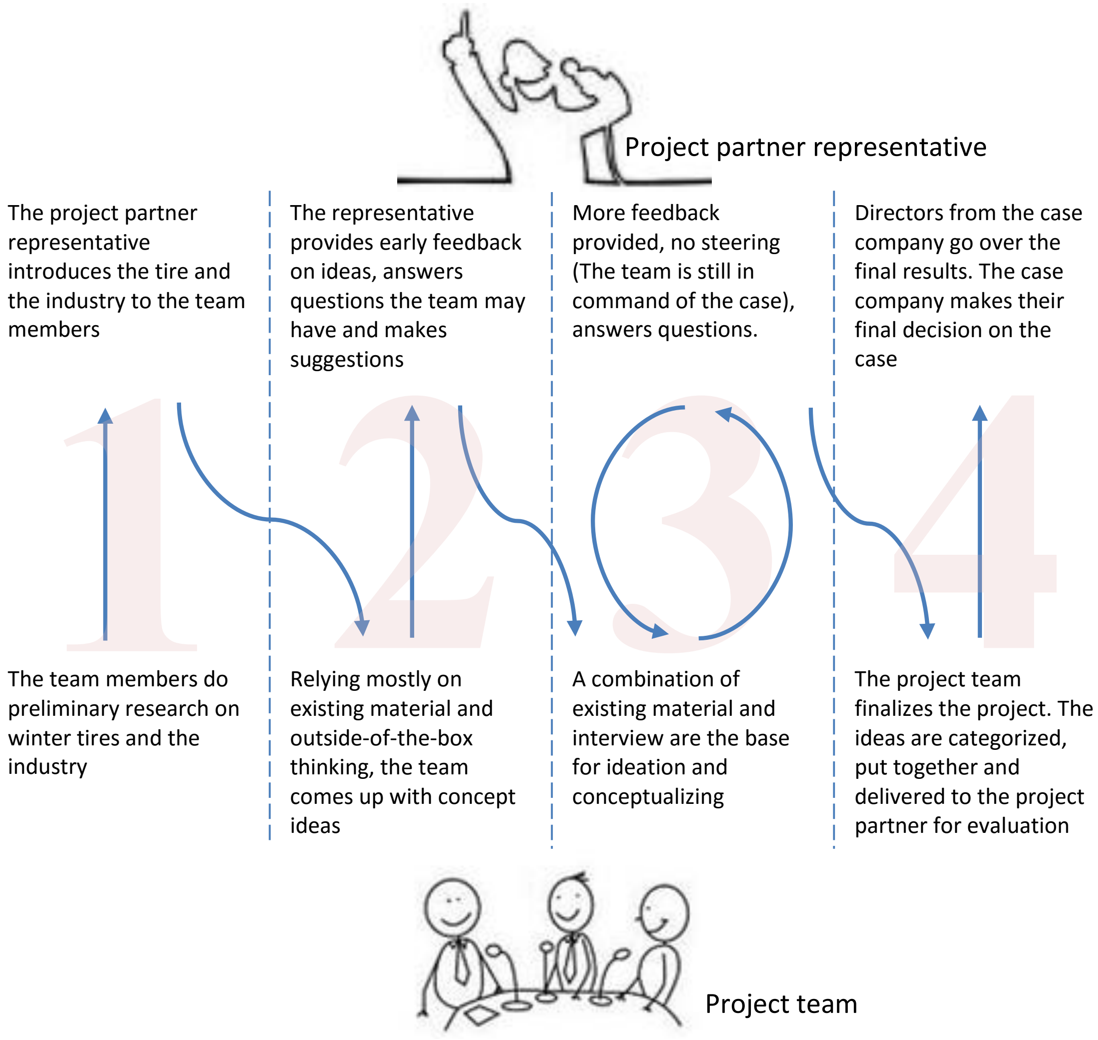

Figure 48. *The adaptation of the Delphi process used throughout the project.*

As opposed to the typical Delphi method, or most methods mentioned in the existing literature on TF as a matter of fact, the inexperienced member steered the project into the direction they believed worked best. Perhaps the biggest difference between the typical Delphi method and this modified version was the lack of anonymity; the fact that this project relied on mentorship from the representative to the team, anonymity was not a possibility. Another variation that is noticeable in this new method, compared to the typical model depicted in Figure 14, is the loop of step three. This step becomes the center around which the project revolves. It is this iterative process that allowed the team to come up with numerous concept ideas.

It has already been mentioned many times how the project partners had the task of providing feedback and help. One example of how this constant feedback was of great help for the team was the following example. During some of the brainstorming, the team had the idea of a tire which would not need to be re-pumped, a tire that could be self-regulating, automatically allowing more air in when the pressure was low. Without much thought yet on how to make the previous possible, the idea was pitched to the project partner during the following bi-weekly meeting. The project partner representative, being in constant awareness of developments in the industry as a part of his duties, told the team how this idea was already in the making by other institutions (and would afterwards be available in the market) and recommended this idea should perhaps not be pursued. The idea was dropped immediately. This mentorship is exemplified in Figure 49.

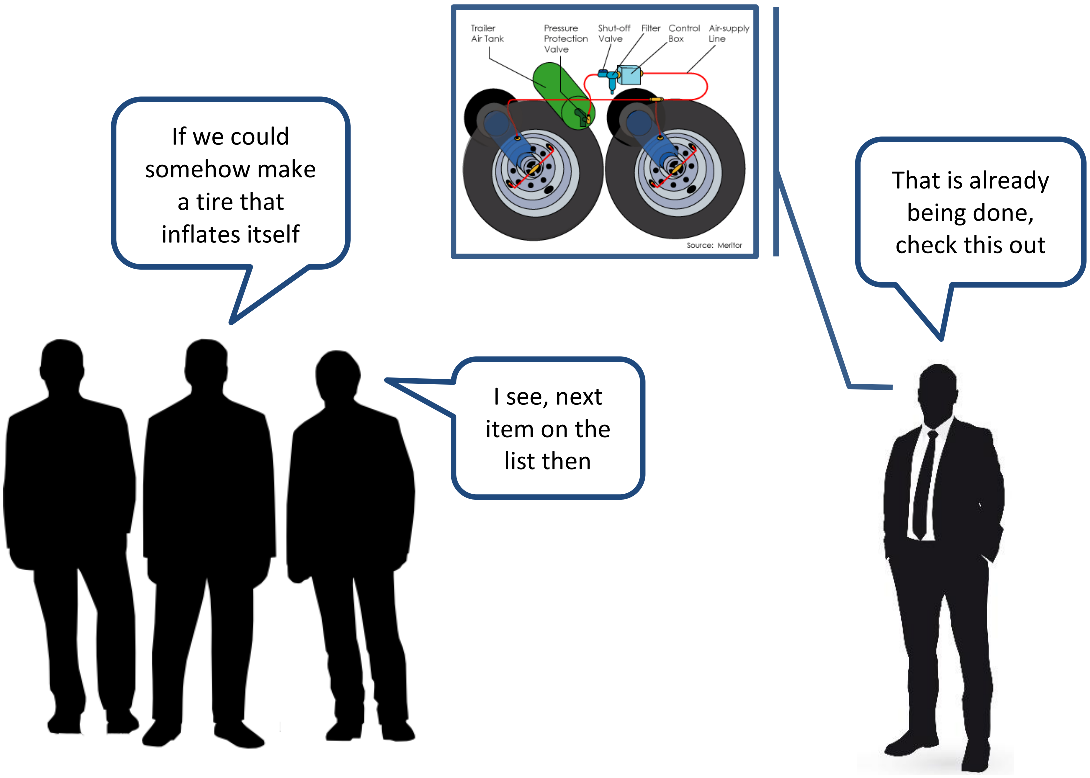

Figure 49. *An example of how the project partner gave guidance and advice.*

As the project progressed, the number of ideas increased. During one of the biweekly meetings, celebrated on November 20th, the project partner set a goal on the number of ideas, this was the first time such an objective was set. The reason for this “sudden” objective was to push the team further. Around the halfway point of the project, the project partner realized the potential of the team and the project, so setting a new objective was intended to serve as motivation. The new desired minimum number of ideas would be 50, while reaching 100 would be considered results beyond expectations. The 50/100 objective presented a challenge. It was around this time that the project team started running low on “idea fuel”. The project became stagnant, the ability to brainstorm had apparently reached a peak. A different point of view that did not depend solely on technology was needed. A new focus based on customer profiling and differentiation of needs was required.

If all customers were the exact same, business would be substantially easier, but this could not be further from the truth. In reality, for the vast majority of companies, customers vary widely along a range or attributes, including product preferences, price sensitivity, retention rates (the amount of staying customers) and responses to marketing and sales tactics. As a result of these factors, customers contribute differently to the firm and hence some are more important than others. (McDougall et al. 1997) In the particular case of the case, it was precisely this range of different customers that allowed the team to continue forward.

The team members conducted a survey that can be loosely compared to the method of importance ratings described in Table 7. The team conducted a brief survey to car drivers. The purpose of this questionnaire was to find out what drivers look for the most when purchasing winter tires. This was by no mean a survey which could be considered of statistical value, as the final number of interviewees came to a total of below 10. The team was not interested in creating statistical data for analysis, it simply desired to hear some product attributes that were perhaps not being considered or had been overlooked. This survey was carried out in early October, it is important to point out how it was carried out into the early stages of the project. Put into the context of the literature review, the team was looking for "satisfiers", those attributes which give the customer that perceived value which makes an offering more attractive than the other. Eventually, partly based the survey feedback and partly based on the perceptions of the team, categories were defined. They are described in Table 10.

Table 10. *The case idea categories.*

Category	Description
Grip	Ideas related to tires that could offer superior grip even during aggressive driving.
Road wear reduction	Winter tires, specially studded tires tend to wear down the asphalt, these are ideas that intend to minimize that effect
Recyclability	This category was about tires which could have a less negative impact on the environment once they reach the end of their life cycle.
Efficiency	Tires that improve fuel economy
Sensor technologies	These are tires that incorporated electronic components
All-season	Tires aimed to be driven all year round, but unlike the all-season tires of current day, these are tires that could potentially be driven under the harshest winters and warmest summers and still offer the driving quality of winter and summer tires respectively.
Tire lifetime	Tire concepts that would have a longer lifetime than the current tires.
Others	Ideas that do not conform to any of the previous categories

A category which was discussed briefly was price, but it was soon discarded. The reason is very simple, when items compete in price point, they can be seen as commodities, but for innovation it is the complete opposite. Furthermore, innovative items tend to carry a higher price than old competing products; this can be in part due to the novelty factor, but mostly because compared to the old available offerings, innovations offer "satisfiers" and "delighters", which justify the increase in price, it is because of the superior perceived value that customers are willing to pay that extra.

Different factors and points of view shaped and contributed towards the final result of the project. Although not very elaborately, the notion of perceived customer value was important in developing futuristic concepts with attributes that could potentially deliver satisfiers and delighters, instead of focusing on technology alone. When thinking back to the literature review of Chapter 2, Figure 50 shows how the actions of the team and the concept relate to one another.

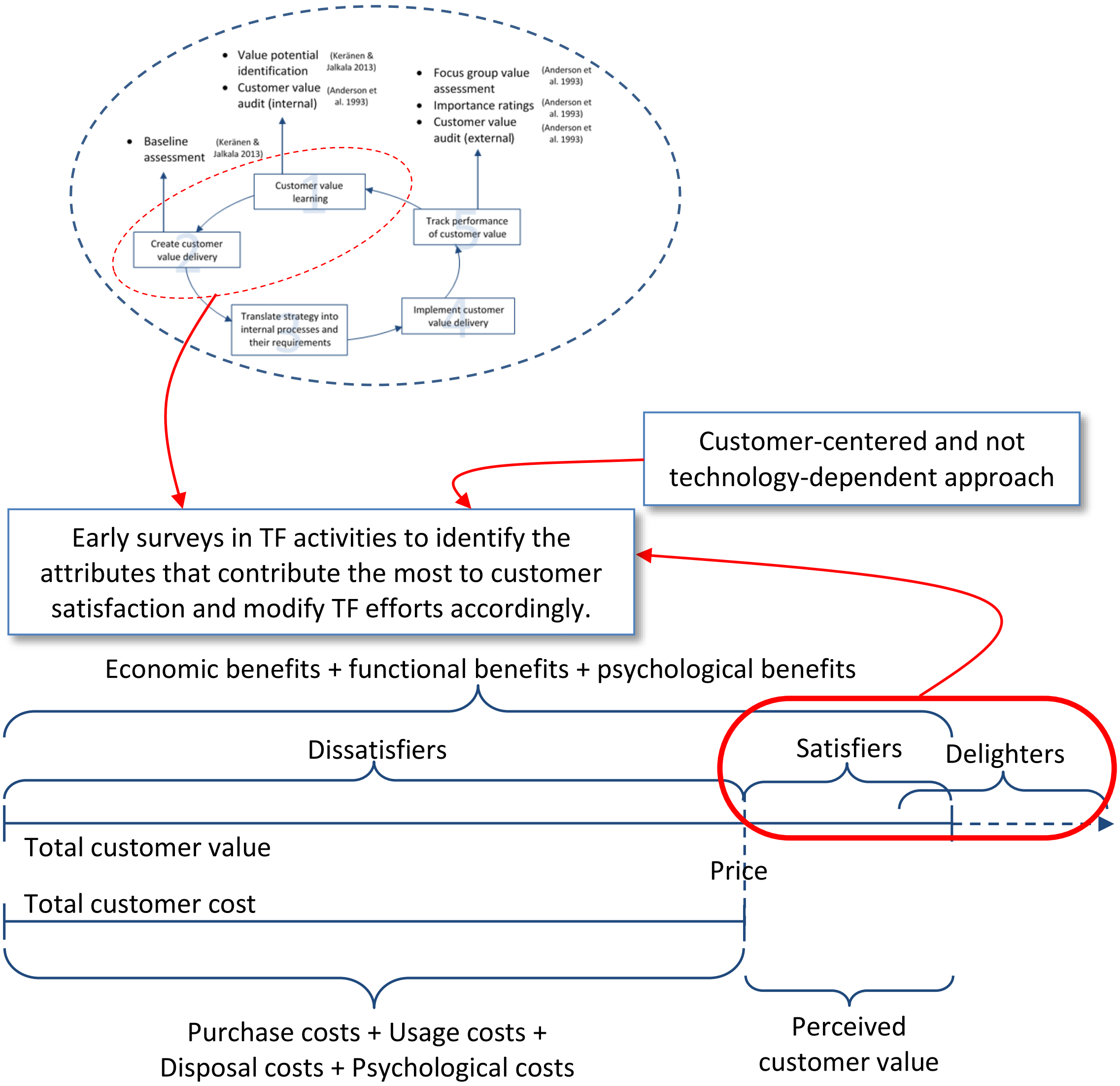

Figure 50. *What the efforts of the team represent in terms of the customer value literature review.*

While the consideration of these attributes did not exclusively dictate the rhythm of the TF activities the project team carried out, they certainly made a difference. Taking these factors into account meant that the team no longer attempted to innovate on the basis of technology alone, but largely parting from customer need and perceived value. Throughout this section some important events and milestones regarding the development of the case have been mentioned. Figure 51 shows them in a timeline.

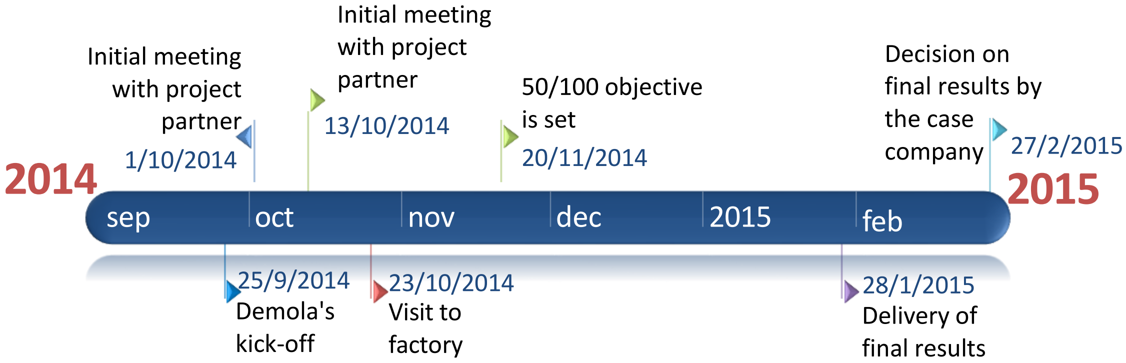

Figure 51. *Timeline of important milestones during the case.*

The next and final section of this chapter presents some of the final results of the case. As mentioned earlier, they do not display much information and remain on very general terms in order to protect the interest of the case company.

5.4 Final results

The project had two main deliverable elements: the list of concept designs and marketing ideas. Figure 52 shows all of the concepts that were part of the final results as classified according to the categories explained in Table 10.

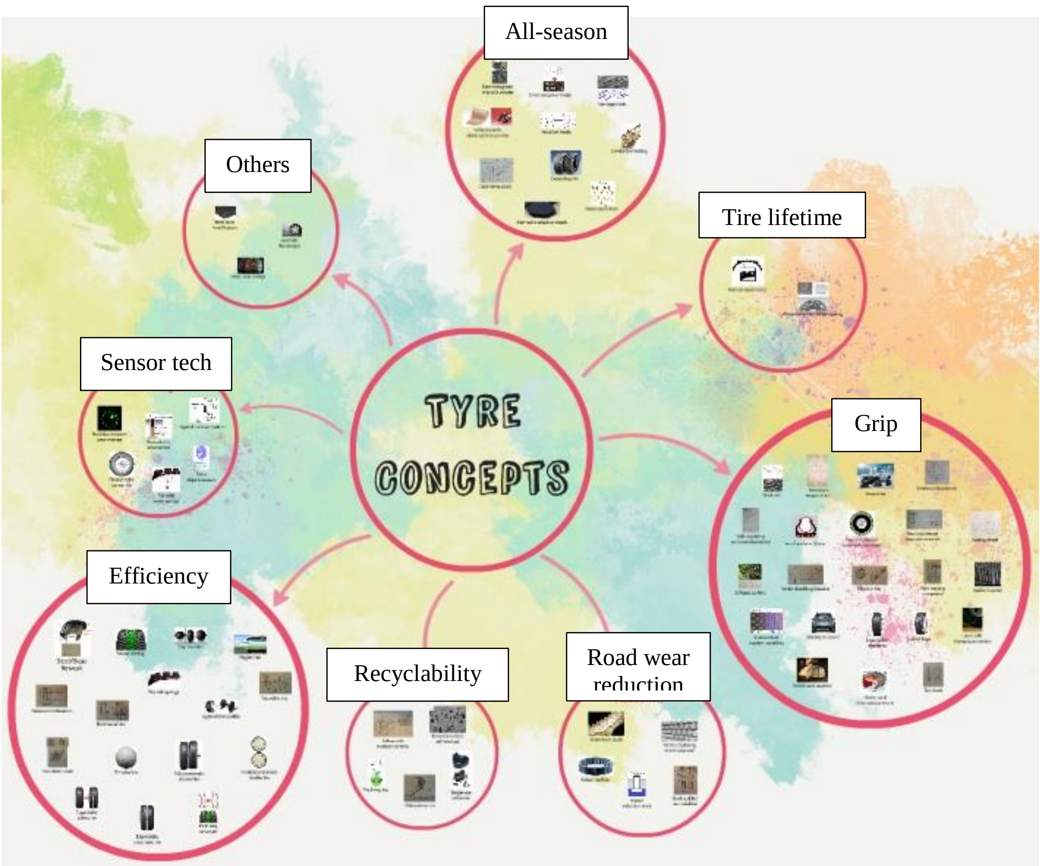

Figure 52. *All of the final ideas categorized.*

The ideas from the previous image can be seen with more detail in Appendix 3. However, the appendix shows no more than the name of the idea and a describing image, no further information is provided due to the protection of interests of the parties involved. The point of including these images is to show the results of the project and to attest how the combination of concepts, i.e. TF and customer value yielded positive results. As mentioned previously, the categories were a result of both the input from the survey as well as from matters the team identified as important. The second deliverable element of the project was marketing ideas. The case company wanted ideas on how to potentially promote the newly created concept tires. Figure 53 shows an example of a promoting image for a concept idea which fall under the category of recyclability.

Figure 53. *An example of promotion material for an eco-friendly tire (part of the deliverables).*

The last two images show what the deliverables of the project were: tire concepts and marketing ideas. The latter was important for the case company as they indicated the direction in which the team positioned their concept tires. Needless to say, the list of ideas was the central aspect of the project. To gain a better understanding of how the case relates to the theoretical framework of this report, three ideas will be explained in a detailed fashion.

Before elaborating on the selected ideas there is a piece of information that is important to clarify. The initial value assessment was limited to finding the most crucial features of a tire according to end users. As specified earlier, this assessment possessed no statistical importance, due to the low number of surveyed subjects, it was rather done for the creative needs of the team. During this assessment the team discovered the following characteristics (with no particular order) are most important for customers when purchasing winter tires: brand, quiet ride, durability, safety, ride comfort, price.

These features represent the dissatisfiers and satisfiers and are the least expected attributes from a winter tire. A revolutionary concept tire, besides fulfilling the previous attributes, should in principle exploit a particular feature in order to offer potential delighters. In other words, the TF conducted during the project would have to be focused on satisfying and surpassing these expectations, rather than just come up with advanced technological novelties.

The first concept idea to be analyzed is called “internal tread matrix”. As tires wear down from usage, its performance decreases as the tread is reduced. The idea behind this concept is the use of biodegradable polymers in conjunction with the regular chemical composites that tires use. As the tires wears down, specific sections of the tire with polymers biodegrade and reveal new grooves. The renewed tread is able to maintain a high performance level throughout the entire lifetime of the tire. This concept and its dissatisfiers, satisfiers and delighters is shown in Figure 54.

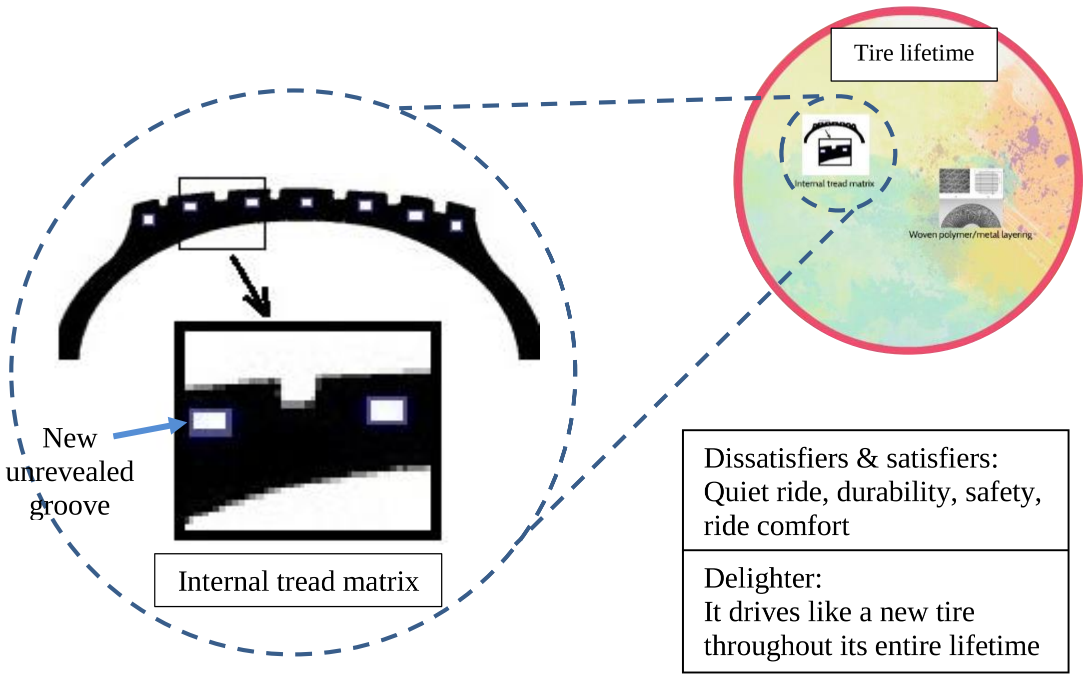

Figure 54. *Internal tread matrix tire concept.*

The second concept is called “shape shifting tire”. This is a tire which is able to slightly change its shape according to need (The way in which the tire is able to change shape will remain undisclosed). In its regular form, the tire makes full contact with the ground (just like a regular tire does) for instances such as rapid acceleration, braking and cornering, where maximum surface contact is needed. For driving instances when there are no demanding conditions, such as driving at a steady speed and subtle acceleration/braking, the tire shifts its shape to exert less surface contact. Since most driving occurs according to non-demanding conditions, the decrease in rolling resistance would decrease fuel consumption. This concept as well as its dissatisfiers, satisfiers and delighters is shown in Figure 55.

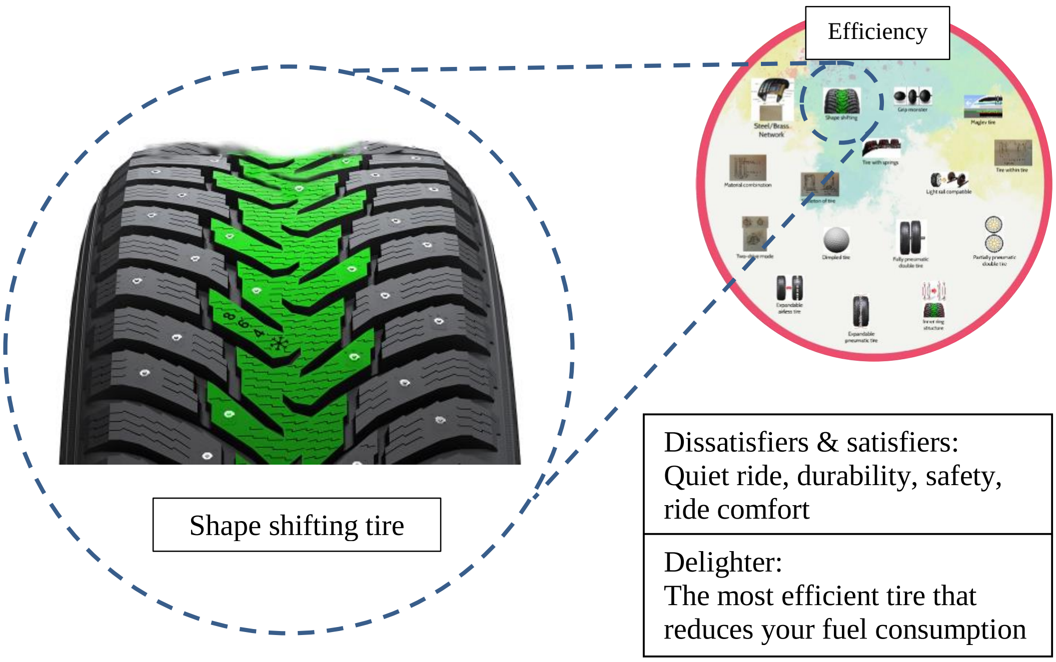

Figure 55. *Shape shifting tire concept.*

Although there are currently in the market some tires with some degree of computerization, this concept goes beyond the current offerings. This concept tire is a completely “digital” product. This concept tire has an array of chips and sensors that allow it to: measure the tire pressure, identify and locate punctures, tell when tire rotation is needed, measure the internal temperature, measure tread depth (wearing out) and most importantly, learn about the driver and help him/her optimize their driving skills. This concept tire communicates with the computer of the car and other smart devices; this is a tire which “talks to its driver”. This concept as well as its dissatisfiers, satisfiers and delighters is shown in Figure 56.

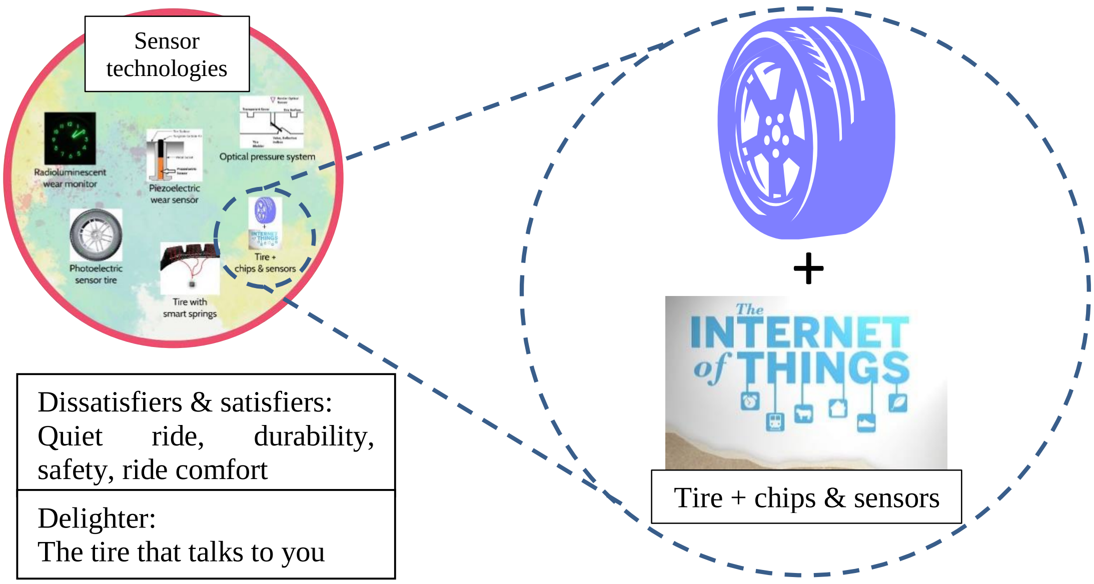

Figure 56. *Concept of a smart tire with chips and sensors.*

The previous ideas may sound far-fetched to different extents, but these unusual concepts were precisely the type of input the case company desired. Tire experts would hardly ideate such concepts, as they are plagued with too many unknowns and too many “impossibles”. Before these concepts can be anywhere close to becoming a reality, there are too many factors and supplementary technologies that must move forth.

While the three previous concept tires involve technological advancements that are not available in current day products, the main objective behind these concepts is to offer true customer value in a way that is not currently present in the market. The way this value offer could potentially be executed is through the creation of a technologically advanced tire. This is a match between value-centered normative and exploratory TF, as is show in Figure 16. Figure 57 shows this match in the particular cases of the three analyzed concept tires.

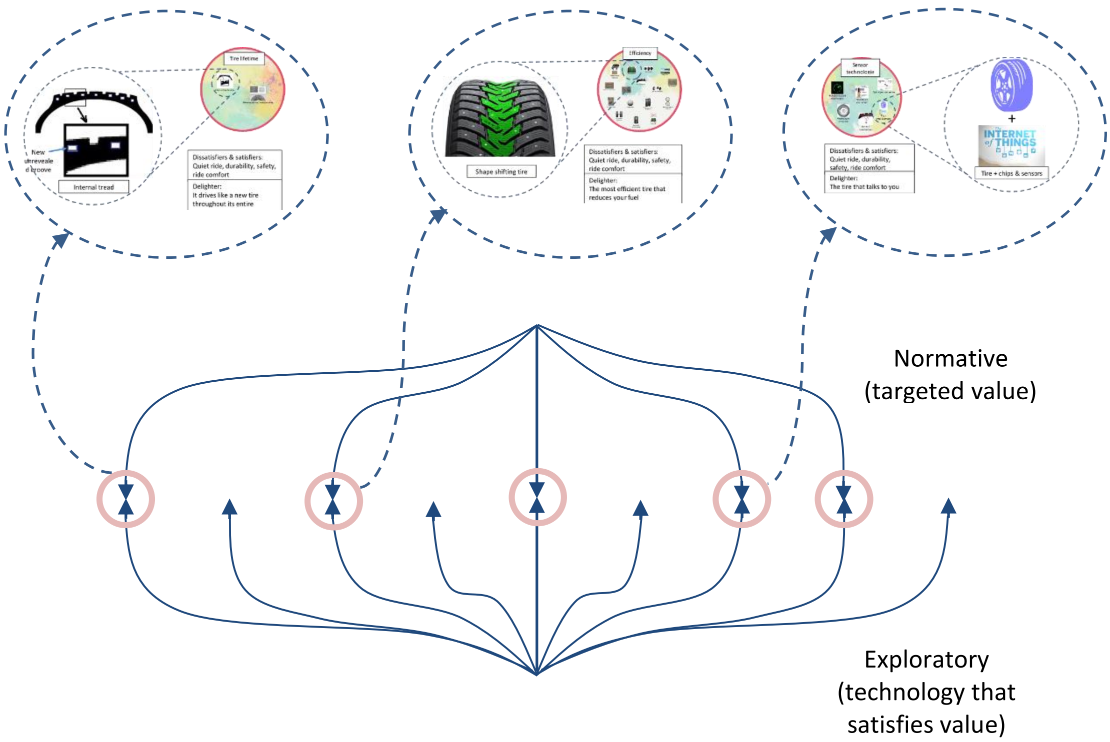

Figure 57. *Fit between normative and exploratory forecasting of the previous three concept tires.*

As for the final results and the decision of the case company, the project can be considered a success, since it was licensed under level 1, according to Table 1. As described in Section 1.3. During the project, the team worked independently from the company, however, once licensed, the project results had the potential of having an even greater impact on the actions of the company.

After the decision on the final results was made, the team could not help but think what could have been done in order for the project to acquire a higher level license. Perhaps the team could have included the concept of customer value earlier on. Perhaps just simply a larger number of ideas would have been required (Which could have been easier with more team members), or perhaps more marketing ideas would have been necessary (Outside the scope of this thesis). Nevertheless, the project was successful and the framework was proven.

To summarize, this chapter described the case of this thesis. The first section described how the project was born and what the expected outcomes were. In the section that followed, the main parties involved in the development of the project were listed and their roles were mentioned. Section 5.3 explained some of the most important events during the project development and their relation to the literature concepts of earlier chapters. Finally, this final section delivered some of the final results of the case. In particular, three sample concept tires where described more thoroughly (although not entirely), it was shown how these concepts were created on the basis of customer value and not technology alone. This was proven through the concept of dissatisfiers, satisfiers and delighters. It is also important to mention how these concepts where explained as a function customer value-centered normative and exploratory forecasting.

6. INNOVATION ROADMAP

6.1 Value-oriented technology forecast

When technologies are solely discussed in scientific panels and R&D environments, any prediction concerning its future adoption becomes challenging. Once a product or service is introduced to the market it is simple to gain insight on the potential of the new item through market surveys, for example (Bouwman & van der Duin 2003). This opinion strictly indicates that there is a need to measure the potential of a recently launched technology, in order to find the optimum market fit and thus offer true customer value.

The previous notion can be extrapolated to longer-term activities. The same value assessment could be made in technology efforts at earlier stages, as early as long-term TF. By somehow assessing the potential customer value any given future innovation can offer, regardless of how rudimentary this assessment is, experts could find ways around uncertainty factors. It could be used as additional guidelines during the entire TF process, the premise of this way of thinking is to move away from technology centered TF and step into costumer value-oriented TF, this change of mentality is put into a simple example in Figure 58.

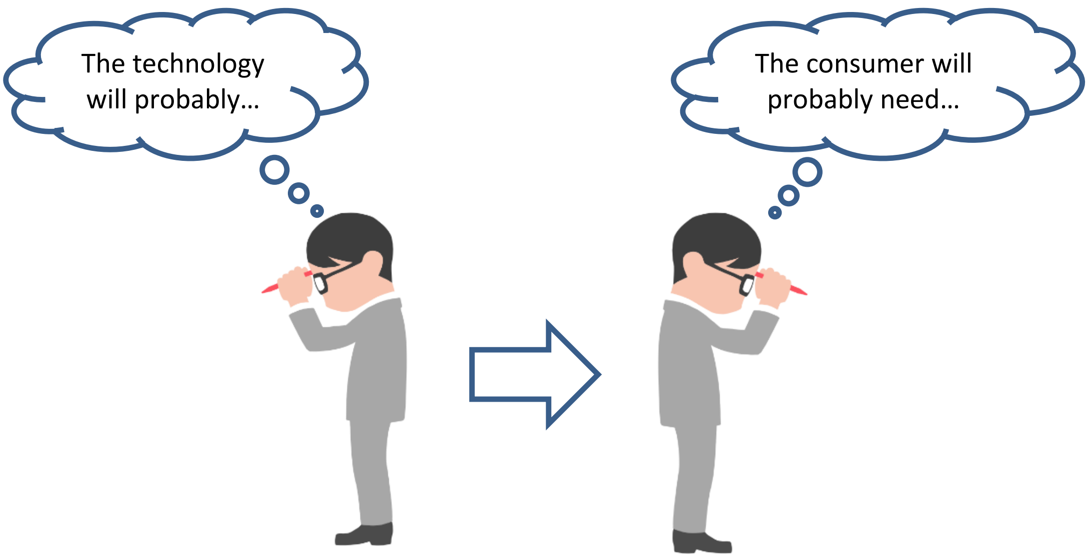

Figure 58. *Shifting the TF paradigm from technology to customer value.*

Bouwman & van der Duin (2003) state that technology explorations, such as TF, show how a specific technology is developing, but it offers limited information as to the different ways in which it can be applied. This open gap further opens the door to customer value. The most important outcome of TF activities, is not the technology itself, but its possible applications. By understanding what a technology can do and analyzing the benefit it can offer, it is possible to find additional uses to it. It should be highlighted that the new framework does not suggest to altogether step away from the traditional approach, but simply to gain a new one which could provide useful new insight.

6.2 The shift from experts to inexperienced individuals

One of the foundations of the framework of this thesis is the inclusion of inexperienced individuals, which defies the normal practices of TF. Authors usually mention how experts are at the most basic level of TF activities. Table 11 shows the authors that make this asseveration. The table has been divided into authors that explicitly mention experts as the driving force behind TF and authors that make no mention of it as such, but through either their theoretical review or their empirical cases show the structure of it.

Table 11. *The mention of experts as TF performers during the literature review.*

Mentioned	Authors
Explicitly	Bouwman & van der Duin 2003; Brownlie 1992; Cetron & Ralph 1971; Cetron 1969; Coates et al. 2001; Fye et al. 2013; Harell & Daim 2009; Jantsch 1967; Kuwahara 1999; Lemos & Porto 1998; Lin et al. 2010; Martino 1993; Martino 1999; Mishra et al. 2002; Mitchell 1992; Porter & Watts 1997; Porter 1999; Porter et al. 2011; Wheeler & Shelley 2010.
Implicitly	Anderson et al. 2008; Anderson et al. 2010; Daim et al. 2008; Linstone 1999; Martino 1980.

In regards to the literature review, there is one author who makes the mention of common inexperienced individuals during TF activities. Bouwman & van der Duin state how during TF Brainstorming is done by experts, but common people can be used to provide feedback. This is only slightly different from the typical approach, while experts are still the sole creators of TF ideas and content, regular inexperienced people may have an effect on them through feedback, however, the inexperienced members are still secondary actors who sit on the sidelines during most of the activities.

As stated by Wheeler & Shelley (2010), forecasters are best at predicting areas in which they have previous experience. While this assumption could be tinted as obvious, it is worth remembering that the same expertise can be bias for decisions and expectations. Cetron & Ralph (1971) mention how forecasters often pay limited attention to easily available information outside their own company and industry.

All of the previous information points out to one clear direction, experts cannot simply hold all the answers, nor should it be expected of them. Section 2.6 mentioned the success rate of technological forecasts by fields. These facts give way for TF that is not purely dependent on expert opinion. Given the right circumstances, the opinion and efforts of inexperienced people as a primary actor in TF activities could be of real value, this is was essential to the effects of the project. Figure 59 shows how this change in mentality was evident in the case of this thesis.

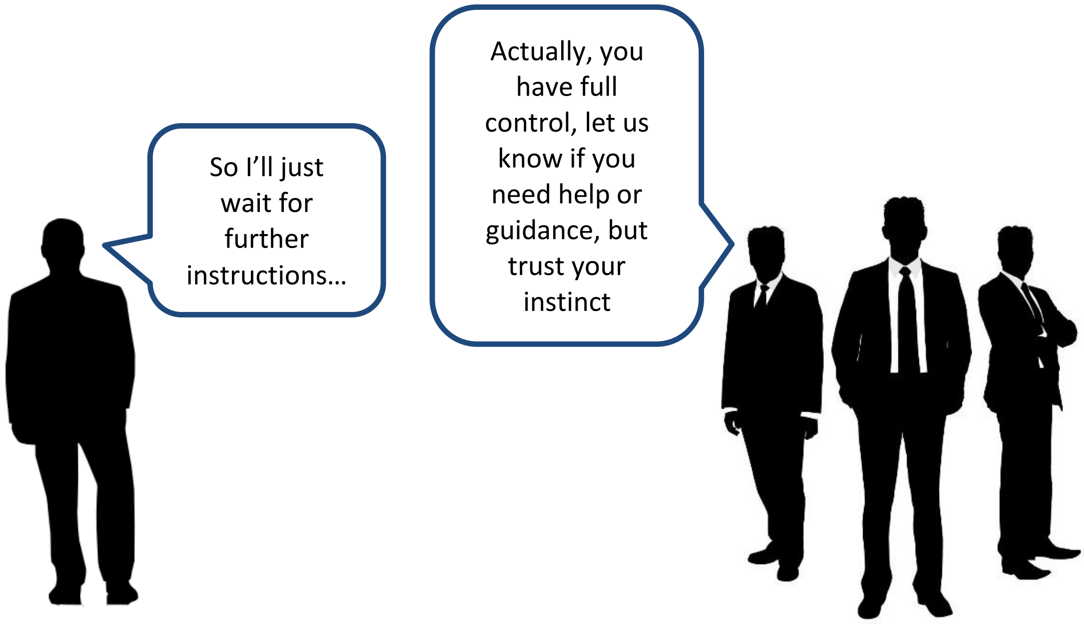

Figure 59. *The opinion of inexperienced people can have more value than what could be initially expected.*

The opinion of inexperienced students, such as was the case of the case, can be help battle expertise blindness or expert bias. It is of the utmost importance that these efforts are systematic and congruential, such as the modified Delphi approach of the case. This process was structured and iterative and it had clear objectives. It is important to acknowledge the limitations of this approach, while the lack of knowledge and experience provides a fresh look on things, any analysis coming from this method will not have the level of sophistication that expert studies would.

6.3 The innovation roadmap

Garcia & Bray (1997) define technology roadmap as a plan to guide progress towards a goal. By extension, technology roadmap is the thorough plan that conducts the efforts of technology exploration towards a goal.

Technology roadmapping consists of projecting major technological elements of product design and manufacturing in order to achieve desirable milestones; these roadmaps can extend several technology or products generations, 2 to 10 years (Coates et al. 2001). A technology roadmap offers a view of the future of technology and science for decision makers. As an analogy, technology roadmap could be seen as technology-centered strategic planning.

When performing TF, it could be easy to get carried in the technology itself and forget about everything else. According to Harell & Daim (2009) it is often that a new technology needs complementary technologies in order to be successfully implemented, yet it is not uncommon for these to be lagging.

The first phases towards a technology roadmap can be considered from Brownlie (1992) and his steps for an all-encompassing technological growth of a company. It begins with top managements and falls down to every step of the ladder. They are:

- Integrating R&D to business strategy
- Identifying technological threats and opportunities
- Formulating research strategy and objectives

Based on the literature review of Chapter 2, it can be argued that the abovementioned elements are no different than the regular actions of TF. These actions were mentioned either explicitly or implicitly during the literature review. There are several authors who have their own way of reviewing a technology roadmap. The author of this thesis has designed a roadmap which is a result of the combination of literature review and the case analyzed throughout this report. Figure 60 shows this model.

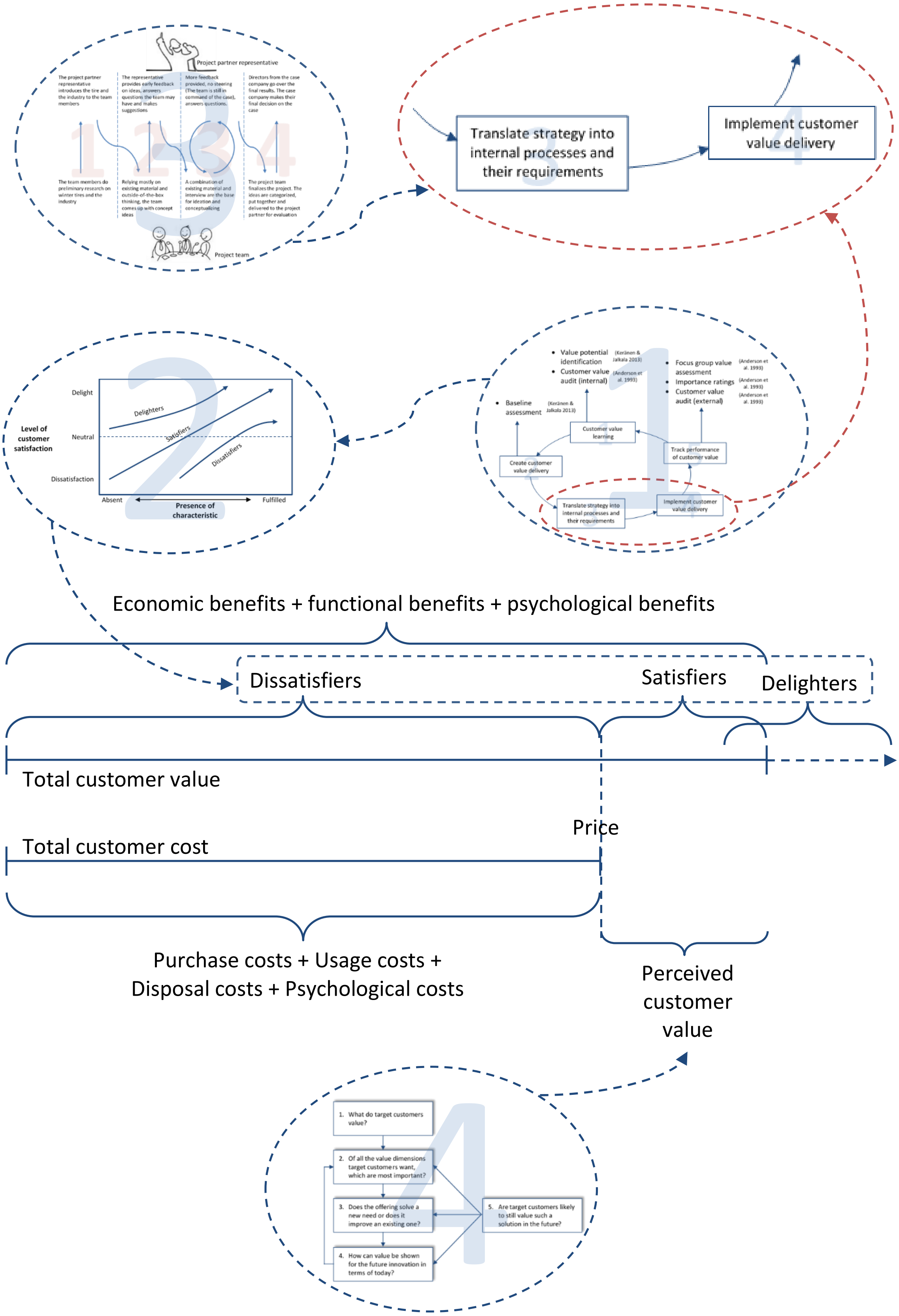

__Figure 60.__ The innovation roadmap.

Although it is visually impacting, the innovation roadmap presented in the previous page is merely a collection of the different framework dimensions and case data used in this report. The roadmap begins with step 1, the holistic value assessment model. This assessment model has the objective of coming up with the attributes and characteristics of the forecasted technology that ultimately satisfy end consumers. In step 2 these attributes are put into dissatisfiers, satisfiers and delighters. These three types of attributes equal the total customer value (and more, it was explained how delighters offer an extra customers did not even know existed). Once the long-term customer value has been established, the technological exploration is done. In this particular case, TF was done through a modified version of the Delphi methodology (step 3). This interaction of steps 1 & 3 is the normative and explorative TF that has been used throughout this report. Finally, step 4 (the innovation value determination process) is a way to make sure the product offers perceived customer value, i.e. the difference between the sum of benefits and the sum of the costs. Step 4 can be seen as a double check for step 1.

As has been highlighted numerous times, this framework has been built with one imperative in mind: the participation of inexperienced individuals as the main actor behind TF. Following this roadmap the forecaster is guaranteed to obtain truly customer value-oriented technological forecasts. There is no guarantee that forecasts under this roadmap could be correct. Inaccuracy will always be an innate trait to technological forecasting.

6.4 Further case development based on literature review

This thesis came to conception after the case was done, while the basic literature dimensions were the driving forces behind the project, it was not possible to apply all of the framework created in this chapter to the case. The purpose of this section is to describe how the case would have further benefitted from the full application of the innovation roadmap framework.

The first and perhaps most notable area of opportunity of the case was the initial approach to customer value determination. The project team conducted a very brief and informal survey in order to determine the dissatisfiers, satisfiers and delighters. If the team would have taken a more formal approach, perhaps different data would have emerged and as a result the project could have taken a slightly different direction; or it would have obtained better results. The reason why customer value determination was performed in such an informal manner was because the team was not aware of the following methods at the time of the project:

- Baseline assessment
- Value potential identification
- Customer value audit (Internal and external)

- Focus group value assessment
- Importance ratings

The aforementioned methods were explained in Section 3.3. Previous knowledge of these methods is not necessary in order to apply them, they are rather straightforward and can be executed by most people. One more tool which could have been of benefit for the case development is the use of scenarios. At the time of the case development, these tool was unknown to the team member. Figure 61 shows how scenarios play out alongside the innovation roadmap.

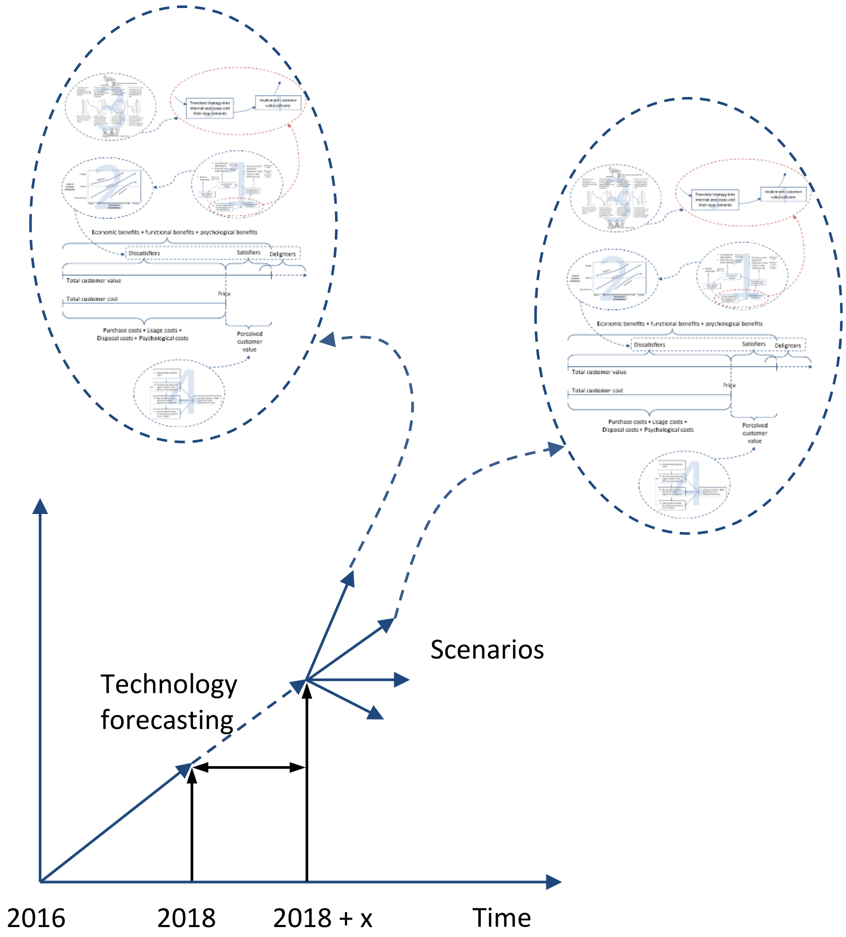

Figure 61. *Scenarios applied in conjunction with the innovation roadmap.*

Scenarios consist of making up alternate realities once the forecast has been completed. The forecasted technology is extended beyond the initial time frame under the newly introduced conditions. Scenarios can be realistic situations but tend to work better when they follow Far-fetched direction and even right down catastrophic or bizarre. The following are example of scenarios that could have been used in the development of the concept tire case:

- If global warming escalated dramatically all of a sudden, how would it affect winter tires?

- If all cars were to become electric over the next ten years, how would it affect winter tires?
- If flying cars were invented within 15 years, what impact would it have on winter tires

It is obvious that the more bizarre a scenario is, the less likely it is to become truth. The real objective behind scenarios in parallel with the innovation roadmap is to spark a different kind of thinking that could originate even more original ideas.

No method is perfect, but the current innovation roadmap has been logically introduced with many factors taken into account in order to complement current TF methods. With all the pros and cons, or better said, the rights and wrongs of the case under study, the author of this thesis believe the study performed can be considered reliable, especially with the backing (licensing of end results) of the project partner.

This chapter brought forth the new framework of innovation platform. The first section of this chapter reassessed how in this framework, technology comes second to customer value when it comes to forecasting. Section 6.2 emphasized the importance of a switch in roles as main actor of the innovation roadmap. Acuity and a progressive way of thinking is needed in order for a company to let experts step aside and allow inexperienced students take the lead as in the study case. Section 6.3 shows how all of the previous paid off and it introduces the innovation platform. This last section identified weaknesses in the study case that were mainly due to the lack of background knowledge on the topics discussed throughout this thesis, since they were not available at the time of the study case. Regardless of this inability to perform a more thorough study, the results of both the case and this thesis can be considered satisfactory.

7. CONCLUSION

In a highly competitive market, companies must fight on different fronts to outperform their competitors and guarantee profitability. Technology forecasting is a discipline that may often be overlooked. For some, technology forecasting could be seen as a great crystal ball which attempts to predict the future. The reality could not be farther from this playful assumption. Whenever a firm makes any decision about its future, whether it is short-, medium- or long-term, that firm is already engaging in forecasting. When these decisions are related to technology, then it becomes clear that all companies actively engage in technology forecasting. What sets leading firms apart from the rest is the level of structure in their technological explorations. Regardless of the degree of orderliness of these technological efforts, the main problem remains the same; technology forecast is mostly, if not entirely, a technology-based approach. Simply put, often technologies are brought to life in an attempt of a company to establish its superiority over the rest, only to be then forcefully pushed onto the consumers. If most of the processes of the firm are nowadays customer-oriented, such as sales & marketing, product design and even manufacturing, then technology forecasting should be no different.

This case was conducted to offer a customer-first alternative solution to technology forecasting, where forecasting efforts, even in the early stages is driven by the desire to satisfy and exceed customer needs. For this purpose, the objective of this thesis was to introduce a new forecasting framework which completely changes the technology-based approach. This framework was born out of the careful combination of key elements from the abundant literature on technology forecasting and customer value. An added element which allows progressive out-of-the-box thinking, which stays away from technology and focuses on customer value was the variation in the main actors. Under the new approach, inexperienced individuals take the role of experts of steering the project into the right direction, while experts are left with the role of assistance and guidance. The viability of this framework was tested in real life via an innovation project done as a part of the Demola Network in joint work with a project partner. The project partner presented the task and offered help, Demola set up the working environment, criteria of success and practicalities, and the team took over the project to the best of their abilities.

The important findings from this thesis is that the innovation roadmap, with its no-experts customer-first approach can actually contribute valuable ideas to the company, ideas which could otherwise never come to life. Although arguably such a team may come up with ideas that may seem technically unfeasible (for the short-term at least), there is no doubt that the revolutionary thinking behind the project provide a fresh new outlook on old matters. Moreover, because of the abundancy of concepts of customer value present in the innovation roadmap framework, results are inherently on the lines of market pull. Furthermore, because of the condition of inexperienced (though with expertise in their own areas) individuals as the primary actor, such a project can be started with relative ease. The primary requirement for such a project is a company with an open mind and progressive thinking which is not afraid of exploring new boundaries. The result of the empirical study, i.e. the project, can be considered a success. The project company decided to license the project results, which means the firm saw value in these results and could perhaps use them in the future.

Other findings of this thesis relate to the marketing material that accompanied the list of concept ideas as part of the end results. Working with a customer-first framework means that all of the results are “customer-friendly”, or in other words, results along the lines of demand pull. What this signifies is that the innovation roadmap framework not only generate results that are easily tailored to the demands and needs of the customers, but this results are more marketable. The ideas resulting from the use of this new framework can be more easily sold to the end consumer.

Even though the framework proved to be a success during the empirical study, it should be stated that this model does not come without its limitations. The project gathered 3 members with absolutely no knowledge of tires nor previous experience in the industry. Even though tires are technically complex items, learning the basics of it is a relatively easy task. That being said, the innovation roadmap framework would most likely not work with overly technical items or industries. For instance, a project attempting to forecast the future of computer processors would be a difficult task for individuals without ample knowledge of electronics. Similarly, the innovation roadmap framework should only be used to forecast technologies in its broadest sense. The project under study had the objective of finding future tire concepts. However, if the project would have consisted of, for instance, forecasting the rubber compound of the tires of the future, the new framework would have been rendered inadequate because such a project would require a specific know-how and a significant period of familiarization with the topic.

The scope of the innovation roadmap could be extended to adequately function wit projects as the ones mentioned above (Forecasting computer processors and rubber compounds). A project team which included some member(s) with intermediate knowledge of the topic. For example, such a project could use students who are at an advanced stage of their studies but do not yet have ample work experience. The argument is that students who have no yet had many years of work experience are still able to think outside of the box even on topics that they “dominate” to a certain degree. These students do not yet have a tunnel vision that come naturally with long years of work experience. This tunnel vision could impede radical TF. In this context, technology exploration efforts would be performed by a combined group of semi-experienced and unexperienced individuals, all of this of course with the guidance and mentorship of industry experts.

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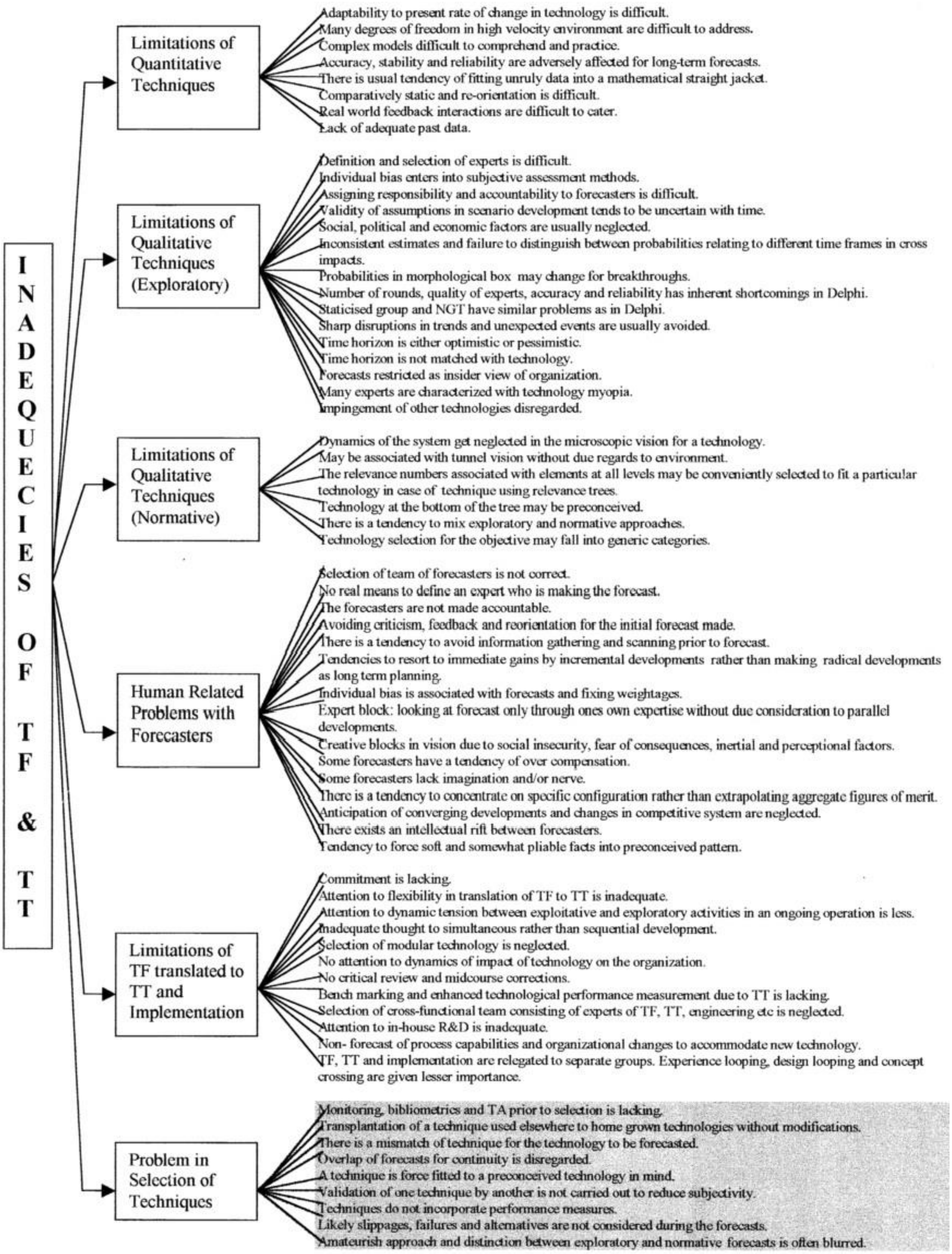
APPENDICES

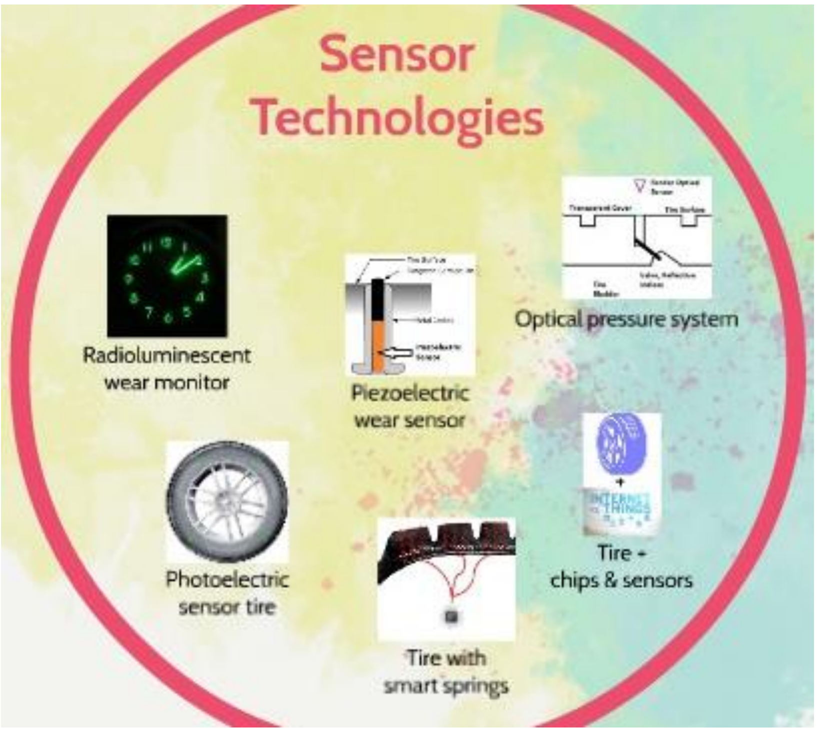
Appendix 1. Analysis of limitations of technological forecast (Mishra et al. 2002).



Appendix 2. Success rate of TF by technology area (Fye et al. 2013).

Technology area	Percent of successful forecasts
Computer technology	59.4
Autonomous/robotics technology	55.0
Communications technology	37.5
Space technology	35.3
Biological technology	26.9
Ground transportation technology	26.5
Energy and power technology	25.8
Maritime transportation technology	66.7
Air transportation technology	42.9
Physical, chemical, and mechanical system	36.4
Sensor technology	33.3
Production technology	33.3
Photonics and phononics technology	30.0
Materials technology	28.6
Average	36.9

Appendix 3. The concept ideas delivered to the project partner (Name and drawing, no description)




Grip
Shark skin
Secondary support studs
Snow drive
Sectional chambered
Self-regulating sectional chambered
Two-chambered (inner)
Two-chambered (outer with structure)
Two-chambered (separate external)
Training wheel
Octopus suckers
Water absorbing capsules
Elliptical tire
Non-wetting compound
Gecko-inspired
Intermediate traction nanofilms
Braking tire barrel
Expandable elements
Lateral flaps
Layer with changing properties
Kinetic sand covered
Kinetic sand inner compartment
Tire claws


Road Wear
Reduction
Shark teeth studs
Particle capturing
micro-structure
Airless tire filter
Impact
reduction studs
Dual studded
non-studded


Tire Lifetime
Internal tread matrix
Woven polymer/metal layering


Efficiency
Steel/Brass
Network
Shape shifting
Grip monster
Maglev tire
Tire with springs
Tire within tire
Material combination
Skeleton of tire
Light rail compatible
Two-drive mode
Dimpled tire
Fully pneumatic
double tire
Partially pneumatic
double tire
Expandable
airless tire
Expandable
pneumatic tire
Inner ring
structure


All Season
Electromagnetic ring with powder
Smart Adaptive Treads
Tire chain/web
Adhesive with rubber particle powder
Adaptive treads
Conductive heating
Expanding tire
Cold-temp studs
Passivated silicon
Alternative adaptive treads


Recyclability
Airless with
multiple sections
Pores for surface
self-renewal
The living tire
Airless dress-on
Single-use
inflatable


Others
Inner layer
modification
Aesthetic
tire designs
Wear color change