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Roadmapping of Emergent Technologies

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Abstract

The following thesis is an investigation of the current roadmapping practices at Volvo with the aim of developing a new method for carrying out roadmapping that better suits the needs of Volvo. The investigative part of the thesis consists of a total of 34 interviews, most of which were conducted at Volvo and the remaining at Ericsson and Tetra Pak, as well as an in-depth review of existing literature on the subject. The findings from these interviews together with the literature review will then serve as a basis when developing the new roadmapping method designed to better be able to evaluate emergent technologies from a value perspective compared to the processes in use today.

The developed roadmapping method is based around workshops with, ideally, 10-15 participants. These participants should come from many different business functions, and thus be cross-functional, in order to create as good a roadmap and get as much details as possible. In the workshops the actual roadmap is made by posting sticky-notes on the roadmap architecture. After the workshop is completed the roadmap is translated into a digital format. The roadmap is divided into four distinct layers: What creates Use value?, Wanted features, Required technology and R&D projects, and Barriers & Enablers. In addition to these layers the roadmap also has a timescale. A roadmap is created for a technology within a pre-chosen feature area where it is interesting to investigate how and in what ways the technology can be applied. A roadmap can in other words be seen as a technological forecast for a specific technology within a feature area.

Keywords: *Roadmap, Roadmapping, Value roadmapping, Emerging technologies, Technological forecasting, Workshops*

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Introduction

In this chapter general background information of the Master's thesis, as well as on the company who sponsors the thesis, will be given. Topics that will be presented are the scope and limitations to the study, the general purpose thesis and the research questions that the study aims to answer.

Background

Companies often experience difficulties when it comes to realistically evaluate future technologies and the features that these technologies can help to create. In addition, companies also have problems determining the value of these technologies and features in relation with the cost of developing or acquiring the technology or feature in question. This is due to the high uncertainty of the possible applications and usefulness of a technology in the early phases of its lifecycle. Therefore, the future usefulness and value to both the company and customer is hard to predict. Dickson, Thornton and Graves (2001, p. 518) state that companies need to continuously invest in new technology in order to remain competitive and since resources are limited, they have to be strategically allocated between projects in order to balance the alignment between corporate strategy, risk and reward.

This ties in with portfolio management, that Cooper, Edgett and Kleinschmidt define as *"a dynamic decision process, whereby a business's list of active and new products (and R&D) projects are constantly updated and revised*" (Cooper, Edgett and Kleinschmidt, 2002, p. 2). Portfolio management thus aims to allocate resources in order to maximize the portfolio value, adapt the portfolio to the business strategy and create a balanced mix of projects in the portfolio. High uncertainties in the new technology evaluation process make the project portfolio management depend on highly unreliable estimations of future value.

Using and developing suitable roadmapping processes is a way for a company to mitigate these problems, improve its portfolio management and, in the end, gain a competitive advantage. There are many different roadmapping methods described and investigated in the literature but little prior research has focused on the use roadmapping when it comes to technology exploration and evaluation in early phases of a technology's lifecycle. Furthermore, during the literature review of the study only one paper was found to deal explicitly with how to incorporate value thinking into a roadmapping process. Therefore, the aim of this Master's thesis is to investigate how a roadmapping method should be designed in order to evaluate emerging technologies from a value perspective. The developed method will then be tested at Volvo Technology.

Volvo Technology

Since the companywide reorganization of the Volvo Group in January 2012, Volvo Technology, which used to be a separate company within the Volvo Group, is now a business unit in a larger company. The new company is called Volvo Group Trucks Technology (GTT) and was formed on January 1, 2012. Activities within Volvo 3P, Volvo Powertrain, Volvo Parts, Volvo Technology and Non-Automotive Purchasing were merged together to form this new company. The former Volvo Technology is now included in a business unit called Advanced Technology & Research (AT&R) within the GTT. For simplicity's sake, and because it is still used by employees today, the old of name Volvo Technology (VTEC) will be used throughout this report.

Volvo Technology has approximately 450 employees worldwide, most of which are located in Sweden. The mission of VTEC is to "*develop a lead in existing and future technology areas of high importance to Volvo*" (Volvo Group Trucks Technology, 2012). VTEC has two main functions within the Volvo Group (Volvo Group Trucks Technology, Internal presentation, 2012). The first, and largest, is its role as the centre for innovation, research and development within the Volvo Group. In this role VTEC helps to make sure that Volvo stays competitive in the future. VTEC's second function is that it provides Volvo with various corporate functions, such as for example IP management, standards and Intelligence. These are responsibilities that are many times found directly under a company's head-office. Volvo Technology also participates in many national and international research programs. Even though VTEC are developing new technologies to all the different business units within Volvo, most work is focused towards Volvo Trucks. Except the business units within Volvo, some suppliers and Volvo Cars have in some cases also been customers to VTEC.

In this report it is mostly the technical innovation and research side of Volvo Technology that will be dealt with. VTEC works with a wide range of research areas, including for example telematics, logistics, ergonomics, electronics, combustion and mechanics. There are six different Key Technology Areas at Volvo Technology. These areas are each headed by a Technology Area Director and are divided as follows:

- Energy & Environment
- Soft Products & Transport Solutions
- Safety & Security
- Electrical & Embedded Systems
- Process & Manufacturing Technologies
- New Technologies

It is the New Technologies area that is the sponsor of this Master's thesis. The New Technologies area acts as Volvo Group's technology intelligence scouts. Their objective is to scan the environment for emerging technologies and evaluate them in order to see if they might be of interest to Volvo.

Purpose

This Master's thesis at Volvo Technology was initiated due to the fact that the company wanted to increase the customer and market focus in their roadmapping and planning processes. The task was thus to investigate what challenges they needed to deal with and what could be done in order to mitigate any problems.

The purpose of this master's thesis is thus to investigate how roadmapping is currently being carried out at Volvo Technology. These findings, together with a review of existing literature on the subject of roadmapping, will then serve as a basis when developing a roadmapping method that is designed to evaluate emergent technologies from a value perspective. This new method should better suit the needs of the company and create more benefits compared to existing processes.

Research questions

In order to fulfil this purpose three research questions have been postulated. The research questions of the thesis are as follows:

1. How is roadmapping carried out at Volvo Technology today?
2. What are the main differences between how roadmapping should be managed according to literature and Volvo Technology's way of working with roadmapping?
3. How should a roadmapping process for Volvo Technology be designed in order to take advantage of the roadmapping benefits described in literature?

The three research questions build on one another and are to be answered sequentially. The answer to the first question describes the current situation at Volvo today. The second question is designed to problematize the findings from the first research question. Finally, the answers to the third question offer solutions to the previously identified problems and will result in a method for carrying out roadmapping at Volvo. In other words, the answer to the third research question will be a proposal for a new roadmapping method that can be implemented as a new way of working with roadmapping within Volvo. This new method will be designed to meet the needs of the company to a higher degree compared to the existing ways of working with roadmapping and the method will be tested during workshops with employees at Volvo.

Limitations

In order to better focus the Master's thesis the scope of the project need to be set. Setting limitations is also necessary due to the time constraints placed upon the project. The limitations that have been decided on are presented below in no particular order of importance.

1. The study will only focus on Volvo's situation. The developed method will be designed for Volvo's needs and will not be tested or evaluated for other companies.
2. No recommendations regarding how to actually identify any potential technologies will be given. Only valuation of already known technologies will be carried out.
3. The thesis will not deal with what Volvo should do in order to capture the value that the identified technologies can create.
4. There are numerous forecasting and foresight methods in existence in addition to roadmapping. But in order to be able to delve deeper into roadmapping and its various subcategories, these other methods will not be examined in any explicit way in this report.

Literature review

This part of the report consists of the findings of the literature review. All of the concepts that are used throughout the paper and that will form the theoretical basis of the analysis and the conclusions will be presented here. The main concepts that will be covered in the chapter include technological forecasting, value and the creation of value, how technology can be valuated and how to deal with uncertainty and risk during this valuation. The chapter will begin with an introduction to general technological forecasting principles. Lastly various approaches to and forms of roadmapping will be discussed in detail.

The concept of technological forecasting

Forecasting of technology has historically been based on guesses and estimations of experts within the field in question (Meredith & Mantel, 1995). This is still often the case in many industries today but Meredith and Mantel argues that it is no longer appropriate since technological development has become increasingly dependent on the interaction between a range of many different technologies, often from very different industry sectors. It is very rare for one single person to have the requisite level of expertise and experience in all involved fields. Roadmapping deals with this problem by having many people with different background and functions present at the creation of the roadmap in a workshop setting.

Meredith and Mantel (1995) define technological forecasting as "*the process of predicting the future characteristics and timing of technology*" (Meredith & Mantel, 1995, p. 1). Thus, the aim of technological forecasting is, according to Meredith and Mantel, to predict future technological abilities and capabilities. The authors also points out that a forecast is not supposed to predict how things will be done, or even actually take profitability into consideration. Forecasting should in this view simply showcase what is possible and at what point in the future it can be available for use.

Saffo (2007) however disagrees with the statement that forecasting is about making predictions. He takes the view that making accurate predictions about the future is impossible. In his view a forecast should be effective rather than accurate. By this he means that a good forecast does not have to necessarily come true, work that the company does will influence the future course of events and, hopefully, set the company on a path that will lead it to a desired position in the future. The task of a forecaster is consequently to "*identify the full range of possibilities, not a limited set of illusory certainties*" (Saffo, 2007, p. 124). Thus, the job is to map uncertainties so that they may be exploited and dealt with in the future. Whether the forecast is accurate or not and turns out to be true is of little importance. This is because of the fact that what we do in the present shapes how things will play out in the future. Because of this it is possible to avoid making a negative forecast come true and to make the future "better" from the company's perspective.

Niiniluoto (2001) supports Saffo's view but takes a more philosophical approach. He explains that some things in the future can be "known" but these things are mostly of trivial and of minor interest. For instance, mathematical statements and formulas will always hold true (2+3 will always be 5 for example), similarly, the laws of gravity can be assumed to be true even in 50 years from now. These things are not very relevant from a company's forecasting perspective however. How the company's state of affairs in the future will look like is of a much greater interest. The problem here is that these events have not yet been realized, since the future does not yet exist. Hence, the best that can be done is to make guesses about the future (Niiniluoto, 2003). Niiniluoto goes on to say that knowledge about the present should serve as a base and be used as "*evidence*" for statements about the future. The future can thus be characterized as a tree where the branches represent different scenarios that can play out under certain circumstances. These scenarios, or branches, have different probabilities of happening, and can be things a company might want to either realize or avoid. The purpose of a forecasting exercise from Niiniluoto's perspective is consequently to give a company a "heads-up" about the future, and what the company can do to influence the future and steer it in a way that is considered favourable.

In addition to the fairly obvious need to plan for the company's technological future, having made a forecast is also useful when choosing what technologies a new project will need and make use of, as well as what external technologies the company's own technology will interact with (Meredith & Mantel, 1995). Some form of forecasting is always carried out within a company (Martino, 1993). This need not always be explicit however as a decision "not to forecast" is an implicit assumption that the future will be static (Meredith & Mantel, 1995; Martino, 1993). This is of course a false assumption and both of these authors urge managers to make more conscious decisions in regards to technological forecasting.

When it comes to regular forecasting Tolfree and Smith (2009) states that it merely sets the scene for what can happen and what is possible in the future. It rarely details how an organization actually can get to this described future state. Roadmapping however, can fill in these gaps as well as help establish a path that the organization can follow into the future (Tolfree & Smith, 2009).

The concept of value

The term 'value' is something that have very different meaning to different people. Even the use of the term in the literature has a tendency to refer to several different phenomena (Bowman and Ambrosini, 2000). A quite common, and fairly straightforward, definition of value is given by Mayhew (2010). He states that value is subjective and multi-faceted and can be defined as *a measure of the utility that is derived from the consumption of a good.* This has the implication that a good will be valued higher by those that can derive the most utility from the consumption of the good. Another implication is that the value of the good is dependent on its availability. For example, in places where water is abundant people are not willing to pay a lot of money for it, even though it is essential for survival. Further, Mayhew (2010) states that the value of a good, such as a product or a service, is commonly measured by its net cash flows. He calls this the *economic value* of the good.

This is in large part in agreement with Menger (1871/2007) who also believes that it is the marginal utility that a user can gain from a good that is the source of the value. In other words, if a product or good satisfy a need but is in large supply it is less valuable compared to if the good where in short supply. Value can thus be said to be a function of the degree of satisfaction that is offered by a good and the availability of the good in question. Menger (1871/2997) also states that for a thing to be valuable all four of the following prerequisite criteria need to be present:

1. *"A human need.*
2. *Such properties as render the thing capable of being brought into a causal connection with the satisfaction of this need.*
3. *Human knowledge of this causal connection.*

4. *Command of the thing sufficient to direct it to the satisfaction of the need."* (Menger, 1871/2007 p. 52).

Menger (1871/2007) argues that value can be of different orders, where things that directly satisfy a need have value of the first order. Value of the first order is built up of value of lower orders. In the example given by Menger, cigars have value of the first order and the second order value come from for example skilled farmers, land and tools. If some cultural changes then make the need for cigars disappear a cigar would not have any value according to Menger's four criteria listed above. In other words the first order value disappears. The second order values still remain however and can be used in new ways to satisfy other needs, and thus create new kinds of first order value. According to Menger (1871/2007) the second and lower orders of value are worthless alone but can be combined to create new combinations that will fulfil a need and create new value.

Bowman and Ambrosini (2000) takes a resource based view and argues that by distinguishing between two separate kinds of value, *use value* and *exchange value*, a better understanding of the concept of value can be achieved. Use value refers to a subjective measure of the perceived value and usefulness of a good (product, service, task etc.) by the consumer of the good (Bowman and Ambrosini, 2000; Lepak, Smith and Taylor, 2007). In other words, use value is an individual measure and can be said to reflect the value that a particular individual think a product has. This also encompass what features the consumer think a product should have, if a product lacks features that the consumer expected in advance the use value perceived by that consumer will decline (Bowman and Ambrosini, 2000). Conversely, if a product has certain features that the consumer did not expect, the perceived use value increases for that consumer. Use value can also be seen as the total amount of money a buyer would be willing to spend on a good if there is only a single source of supply and no other choices (Bowman and Ambrosini, 2000). Bowman and Ambrosini's (2000) noton of Use value corresponds well with Menger (1871/2007) and can be seen as a continuation of Menger's work.

It is important to note that use value is entirely based on perception by individual users (or buyers), and may or may not reflect the true economic value of the good. Another thing that Bowman and Ambrosini (2000) emphasize is that use value perception applies to all purchases, not just for end-consumers. There is little difference between the judgments made by a manager procuring on behalf of a company and a consumer buying a new product.

Bowman and Ambrosini's (2000) concept of use value corresponds well with Mayhew's (2010) definition of value, as outlined above, in that both definitions emphasize the subjective nature of value and point out that it is the perception of the worth of the good that determine its (use) value to the buyer. The difference between the authors' perspectives lays in the translation from value measured in the abstract unit of utility, into monetary terms. As stated above, Bowman and Ambrosini (2000) write that use value can be seen as the maximum amount of money that a buyer is willing to pay for a good. Mayhew (2010) only states that the utility derived from a good can be converted into economic value by looking at its cash flows, i.e. the cost of production and the price for which the good can be sold. Bowman and Ambrosini (2000) goes one step further than Mayhew (2010) in this regard and also introduce another aspect of value that they call exchange value.

Exchange value refers to price (Bowman and Ambrosini, 2000) and is simply the monetary sum that a buyer pays a seller at the time of purchase, i.e. at the time of the exchange. In other words, a product's use value is converted into exchange value when it is sold. Exchange value resembles

Mayhew's (2010) economic value, even though Mayhew do not explicitly make this distinction between the different forms of value. According to Bowman and Ambrosini (2010) exchange value that is retained within a firm can be seen as the same as profit for the company.

Even though use value and exchange value are connected, it is very rare that they are identical. According to Bowman and Ambrosini (2000) this can only happen in certain special monopoly situations. The difference between exchange value and use value is termed '*consumer surplus*', or more colloquially '*value for money*' (Bowman and Ambrosini, 2010). Naturally, buyers prefer products that give them the highest consumer surplus while companies prefer to lower the consumer surplus in order to gain higher profits.

In this report Bowman and Ambrosini's distinction between use value and exchange value will be used. This is seen as a more clear way of discussing value since it encapsulates two separate forms of value. This will in turn facilitate the discussion on this topic by making it clearer for the reader exactly what form of value is intended at the time. Use value is furthermore used in one of the four layers of the roadmapping method that has been developed during the course of this Master's thesis.

Value Creation

In order to define how value is created it is first required to define the sources and targets of value creation as well as the level of analysis (Lepak et al. 2007). Three different levels of analysis are identified by Lepak et al. These are the individual level, the organizational level and the societal level. This thesis will have a focus on the organizational level of value creation. On this level the emphasis is on issues regarding innovation, knowledge creation, invention and management (Lepak et al., 2007).

Lepak et al. (2007) cites Porter's (1985) discussion about value creation within firms. He states that new value is created when "*firms develop/invent new ways of doing things using new methods, new technologies, and/or new forms of raw material*" (Lepak et al., 2007 p. 184). Thus, new technologies and innovation play an important part in creating value for an organization. Priem (2007) suggest that value creating innovation is something that increases, or creates entirely new use value, as perceived by consumers. Value creation can in this view essentially be seen as including any activity that provides customers with a greater level of benefits and novelty than they currently possess (Lepak et al., 2007).

It is also pointed out by Lepak et al. (2007) that there exists different potential targets for value creation within a firm; it is not only customer value for example. Some examples that are provided by the authors are, in addition to regular customer value, earnings for owners, pay for employees and taxes for society. By definition, different groups of people have different views of what is valuable (in terms of use value) due to unique knowledge, goals and context that leads to different perceptions of the value. This also means that different groups of people have different opinions of what will create the greatest profit for the company (or exchange value retained within the company). These viewpoints may even be at odds with each other. For example, investors might favour value creation activities that lead to increased short-term profits while a manager might to sacrifice some short-term profit in favour of a higher expansion rate and more gains in the long run. Bowman and Ambrosini (2010) have a similar discussion of what value means to different stakeholders of a firm. They divide an organization's stakeholders into four main groups: customers, suppliers, investors and the firm itself.

As stated in the ‘The concept of value’ section above, value for consumers can be argued to mean consumer surplus. That is, consumers want to optimize the ratio of acquired use value and the exchange value paid for the use value. Suppliers, on the other hand, are supplying a company with use value and in return get exchange value from the company. Suppliers consequently want to optimize the received exchange value for the supplied use value. Investors have another view of what constitutes value for a company. Investors supply a company with capital, i.e. a monetary sum. This sum of money is given based on the assumption that an even greater sum of money will be returned to the investor in the future, a return on the investment. Bowman and Ambrosini (2010) argue that this can be seen as the investor supplying the company with exchange value, in return for more exchange value in the future. In other words, investors want to optimize the exchange value returned for the exchange value invested.

In another article the same authors state that firms are mainly established to serve the interests of their equity owners, in other words, their investors (Bowman and Ambrosini, 2007). Production is thus carried out in pursuit of profit (retained exchange value) and an expanding stream of exchange value that can later be divided amongst investors in the form of dividends.

A company can be viewed as being both, on the one hand, a customer of use value, and on the other, a supplier of use value (Bowman and Ambrosini, 2010). It buys use value from its suppliers, refines it and then sells the newly created use value to its customers. When acting as a customer, the firm tries to optimize the use value purchased for the exchange value given to the supplier. When in the role of the supplier, the firm instead wants to optimize the exchange value gained for the use value sold.

So how then does a firm create use value that its customers will be willing to buy? Resources purchased from suppliers as input to the process (for example, machines, steel, computers or flour) cannot “*transform themselves into anything other than what they are*” (Bowman and Ambrosini, 2000, p. 5). In order to transform these inputs into something with a greater use value they need to be worked on. This means that people are required in order to create new and greater use value from the resources acquired (Pfeffer, 1995). Bowman and Ambrosini (2000) also expand this to include other less tangible resources like information and brands.

Moreover, the authors point out that even though use value is produced it does not necessarily mean that exchange value will be realized for the company. How much exchange value that will be realized is only determined at the point of sale after the customer makes a comparison with other competing product offerings. And the sale itself only happens if the customer perceives that the product offers more consumer surplus than the competing products (Bowman and Ambrosini, 2000). The authors conclude by stating that you cannot be sure that actual value for the firm, in terms of retained exchange value, has been created in the process of new use value creation. You can only know for certain that a different kind of use value has been created, which may or may not add exchange value to the company depending on if a sale is made or not.

The conclusions that can be drawn from the above are that a company’s profit is the difference between the amount of exchange value realized at the point of sale and the sum of the costs of the inputted resources, and that this profit is attributable to the actions of the employees of the organization. It is only the labour that is capable of creating new Use value, and in turn, new exchange value for the company and its investors. It is also suggested by Nahapiet and Ghoshal (1998) that social connections among employees within a company will provide greater opportunities for information and knowledge sharing that can be combined in a way that will create new organizational knowledge and, in the end, more value for the company.

Bowman and Ambrosini (2007) identify five distinct types of activities that are carried out within companies in order to generate exchange value, and thus profits, for the company and its investors. These activities are either aimed at appropriating revenue from customers or at reducing the costs of the resources that are bought from suppliers. The activities are:

1. *Product creation activities* – The actual production of products or services. The value of this activity can only be assessed in retrospect; if the production does not lead to a sale the activity cannot be deemed to be productive at all.
2. *Value realization activities* – Activities intended to realize revenues from the type 1 activities, for example marketing, customer relationship management and sales activities.
3. *Input procurement activities* – Activities with the aim of moderating the cost flows of other activities. For example procurement, i.e. activities directed at reducing the amount of exchange value/money paid to suppliers in exchange for resources needed in the production process; activities intended to increase production efficiency; and line supervision.
4. *Capital stock creating activities* – Examples include market research, R&D and training for employees. These activities help preserve the firm's current capital stock and support the creation of new resources that will expand the capital stock. The intention with these activities is thus to ensure the generation of future cash flows into the company. The problem is that these activities incur costs today for only potential future benefits, and as such they are often vulnerable to cost-cutting activities.
5. *Firm maintenance activities* – Those activities that are necessary to make the firm function and to conduct business but that do not create any value on their own. Examples are legal work, accounts preparation, tax management and any administrative work. Companies will try to minimize these costs as much as possible.

Two important economic conditions that are necessary for value creation to endure within companies are outlined by Lepak et al. (2007). First, the monetary amount (exchange value) that is paid for a good must exceed the producer's costs (money, time, effort etc.) of creating the good. Second, the monetary sum that a user will pay is dependent on the perceived value of a new product's performance compared to the existing closest alternative product, i.e. a buyer will only buy the new product if he or she believes that it is "better" (offers more use value) in some way compared to older products.

Lepak's et al. (2007) first condition can be compared to traditional economic theory, where it is stated that the price of a good in a perfectly competitive market is equal to the firm's marginal cost of producing the good (Perloff, 2007). This, together with Bowman and Ambrosini's (2000) statement that the maximum price a consumer will pay for a good is the perceived use value (total monetary value) of the good in a monopoly situation, means that the exchange value a company can realize from a produced good must be a sum between the company's marginal cost of production and the value of the product as it is perceived by the buyer.

Value creation will be incorporated in the roadmapping method that has been developed for Volvo during this project. Value creation will, together with the concept of Use value described in the previous section of the report, make up the top layer of the roadmap, the "What creates Use value layer".

Technology Valuation

Valuation can be defined as "*the act or process of assessing value or price*" of a good (Farrukh et al., 2009 p. 44). For technologies, this means determining both current value and future potential value. Financial valuation of a technology is useful in order for companies to better be able to identify and select which projects and technologies to pursue (Thorn et al., 2011). Valuation of a technology also makes it easier to communicate the merit of a project or technology (Hunt et al., 2007). When it comes to valuation of technologies Boer (1998) argues that it differs from more ordinary valuation of financial and physical assets in three main ways:

1. Technology is intangible, especially so for new technology. It is mostly embodied in the skills and experiences of scientists and engineers.
2. A technology can only realize its full value when it is linked to other technologies and/or physical assets. These other technologies may even be owned by competing firms. Valuing the linkages is nonetheless very important in order to get a picture of the real value of the technology at hand.
3. The degree of risk is extraordinarily high when it comes to R&D in general compared to the risk in the regular financial markets.

Boer also notes in a later article (Boer, 2003) that the most important step in technology valuation is to "*understand the business situation and frame the option credibly*" (Boer, 2003 p. 51). A successful valuator thus needs to draw on his or her own expertise, as well as from the knowledge and experiences of, for example, industry experts, R&D managers, marketing executives, economic evaluators and specialists on licensing. This is to get different perspectives that can help frame the issue and the problems. Roadmapping and the roadmapping workshop can be a tool that brings all of these varying viewpoints and opinions together in a synthesized manner. Roadmaps and roadmapping will be discussed in much greater detail later in the chapter.

Discounted Cash Flow (DCF) methods are commonly used valuation tools. Maylor (2010, P.185) defines discounted cash flow as "*the comparison between the value of the return on an investment and the value of the same sum of money had it been deposited in a bank account at a given rate of interest for the same period*". The advantage with DCF is that it considers opportunity cost and the time value of money. In other words, the method takes into consideration the fact that the value of a certain amount of money today is different from what the value will be in the future.

DCF methods are primarily based on cash flow projections (Messica, 2008). In the case of technologies in later lifecycle-stages these future cash flows can be forecasted with reasonable accuracy. Conventional DCF and payback techniques can thus be useful tools when valuating technologies in later lifecycle phases. However, due to the much higher levels of uncertainty, DCF tools are not very good when it comes to valuating emerging technologies (Mayhew, 2010). Messica (2008) even goes as far as to say that it is not possible to use DCF techniques in these cases due to the absence of reliable cash flow forecasts and the high uncertainty regarding the successful completion of the R&D effort. The author goes on to state that in these kinds of situations valuation "*becomes more of an art than a science*" (Messica, 2008, p. 43).

New technologies need a lot more investments to be made into the technology in order to reduce this high degree of uncertainty, otherwise the valuation will be very biased against the new technology and instead favour short-term and relatively risk free investments (Mayhew, 2010). In Christensen, Kaufman and Shih's (2008) view, DCF methods of financial valuation is seen as "*innovation killers*", since managers tend to reject profitable investments in innovation because of using the method incorrectly and in an oversimplified manner.

Christensen et al. (2008) point out two common errors managers often make when using discounted cash flow methods. The first error is the assumption that in the case of not investing in a project, i.e. to do nothing, the current value of the company will persist into the future (line B in Figure 1). The method considers the investment in isolation and assumes that the company's cash flows will be unchanged even in the absence of any investments. Usually they are not unchanging however but gradually decreasing (line C in Figure 1) due to, for example, innovations by competitors, increased price pressure and changes in technology.

The second of Christensen et al.'s (2008) errors relates to the difficulty of estimating future cash flows. A yearly estimation is usually done for the first 3-5 years and then everything thereafter is estimated together into a so called terminal value (also known as horizon/continuing/residual value). This value is quite uncertain due to the market uncertainty and unforeseeable disruptive innovations in the future. To summarize, not investing in new projects is not the same as having unchanging future cash flows into the company. Instead the cash flows of the 'do-nothing' scenario are negative and, as a result, not to invest in new projects will lead to a loss of value for the firm (Christensen et al, 2008).

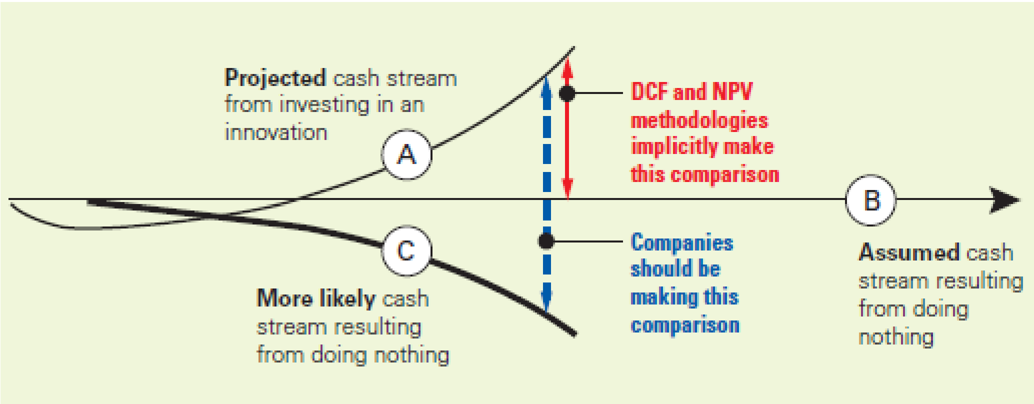

Figure 1. A company's financial position with and without investments (Christensen et al, 2008).

Boer (1998) also supports this view and writes that "*myopic use of cash flow models can also lead to poor decision making"* (Boer, 1998 p.49). Boer further points out that a rapidly growing business oftentimes has a negative cash flow, and that this of course does not mean that the business has no value. This is however often what happens to technology projects when their cash flows are embedded in a business with otherwise lower growth characteristics (Boer, 1998).

Ashford, Dyson and Hodges (1988) argues however that many of the problems with applying DCF and similar methods to the valuation of emerging technologies can be remedied, at least to a certain degree, and that they to a large extent are due to how the method is applied. Examples of ways to make DCF less problematic are according to Ashford et al (1988) to use a more realistic/proper discount rate; not take an over-optimistic view of the no-investment scenario (as line B in Figure 1 depicts); and to account for and try to quantify additional benefits that a technology may bring with it. This is however easier said than done. In addition, new technology will invariably lead to greater complexity and change, which can in itself lead to a bias against the new technology due to a resistance to change (Ashford et al., 1988).

Boer (1998) lists some common mistakes when valuating technology. The first mistake is to set and use a much too high discount rate in the calculations. The author states that this is mainly the result of financial analysts being unfamiliar with R&D and how R&D works. Because of this they do not recognize that a central part of R&D is to reduce risk and that most of the investments will only be made after many of the risks have been cleared and issues overcome. In other words, all of the predicted investment costs are discounted at the initial risk when in actuality only a small percentage of the total investment is made at this high level of risk; most of the investments are made at much lower levels. A drawback of using DCF methods is thus that it is difficult to determine a proper interest rate since interest rates tend to fluctuate a lot. This is an example of a market variable that increases the uncertainty regarding the value of the technology in question.

The second pitfall Boer (1998) identifies is that many managers tend to use the current status quo as the baseline for future investments, not a deterioration of the current situation. This corresponds entirely with Christensen et al.'s (2008) view. Such a deterioration of position is inevitable, especially in the long run, for technology based companies without investments in new technology. This is however something that does not exist in the financial world, not investing in a certain stock will not diminish the value of the alternative investments.

The third of Boer's (1998) problems is that the terminal value is often miscalculated when using discounted cash flow methods. This is of great importance as much, or even most, of a new technology's value will be a part of the terminal value. Boer (1998) states that the problem is the high level of sensitivity to small changes in the discount rate. Conservative assumptions often lead to poor decisions in this area. These three common problems are connected to what Ashford et al. (1988) discuss when it comes to things to be wary of when using DCF methods and what to do in order to improve the use of such techniques for technology valuation.

Other issues that Boer have identified include ignoring the possibility of many different outcomes of a project, i.e. not just look at if a project will make the requested return of investment or not but also to take into consideration the spectrum of outcomes that might be the result of a project; and neglecting the value of the options that investing in a technology will bring with it. Boer (1998) lists four factors that should be considered when valuing the options that a new technology can create:

- *Technology pairing* – a new technology can be paired with other new or existing technologies to create additional value.
- *Strength of linkage* – an innovative technology's value can be very different in different markets, in other words, the linkage between the technology pairs can be stronger or weaker in different markets or products. A technology that is the enabler of a product is especially valuable of course.
- *Polarization of the linkages* – to what degree profits will be realized by the owner of the new technology or the owner of the old and who will be dominant of the two. Rewards must be

shared in some way between the two, but the exact ratio will be dependent on their relative market and technological positions.

- *Size of current and potential markets* – the value a technology can create is dependent on both the value that can be added per unit and number of units produced.

Reilly (1998) also provides a list with examples of attributes that affect the value of technologies. Out of these attributes, the ones that are relevant for early-stage technologies are: how many potential products and/or services can the technology be used in; in how many different industries can the technology be used in and are these markets expanding or not; how easy is the technology to access; how easy will it be to license; how easy will it be to commercialize; are there many competing technologies available now or potentially in the future; can or does the technology fulfil a previously unmet need. Boer's (1998) and Reilly's (1998) points are very similar and Reilly's attributes fit into Boer's four factors. The major difference between the two is that Boer goes into more specific detail about what the factors actually entail.

Mayhew (2010) proposes another framework for valuing technology that is not based on traditional DCF techniques and similar methods, even though it makes use of them to a certain extent. The first step in this framework is to identify and evaluate the potential value drivers of the new technology. A value driver is any characteristic of a technology that can create utility, and as such generate exchange value and profits for a company. This economic value reflects the cash flows to the technology as they currently are. In addition to this, the technology also has a future potential value that it is important to remember to take into consideration when evaluating the technology in question. This potential value can be realized by a range of different investment options. In order to properly determine the potential value, all of these options should be identified and assessed. When quantifying the identified value drivers discounted cash flow methods could be used. Mayhew points out however that these methods are mostly suitable for quantifying the current economic value, and that they are not as suitable to use for future potential value. He further points out that the DCF methods should preferably be accompanied by market-based comparables or other benchmarking approaches.

The next step in Mayhew's framework is to assess the relationships between the value drivers that were identified in the previous stage. Many technologies and their value drivers are likely to be interdependent with other technologies and therefore it is important to consider these relationships. Boer (1998) similarly stresses the importance of this, as outlined above. It should also be kept in mind that many potential investment opportunities will never be exploited and because of this these opportunities will never actually create any value for the firm.

The following step in this framework is to develop robust and practical scenarios where value is realized. The creation of these scenarios serves the purpose of mitigating some of the scepticism people sometimes feel towards forecasts, and thus facilitate acceptance of the valuation forecast. Another effect is that the scenarios will make the valuation parameters and the valuation process more clear to people who did not take part in creating the valuation. After this step is completed it is good practice to test the sensitivity of the valuations. This can for example be done by using regular Monte Carlo simulation and varying the values of the used parameters.

Lastly, Mayhew (2010) recommends using a range of different values, as opposed to using just one single value, when conveying the results of the technology valuation. This is especially important when valuing early phase technologies. He argues that this should be done because it showcases the inherent uncertainty regarding the ultimate commercial utility of the technology as well as providing a better picture of reality compared to one definitive value of the emerging technology.

Technology valuation thus comes in many different shapes and forms and is very important in order to create a proper evaluation of the technology at hand. In the created roadmapping method a qualitative approach to technology valuation has been taken, as opposed to a quantitative approach that results in more or less exact monetary values on each of the investigated technologies. The reason for this is that it is felt that the negative aspects, as described in the literature review above, from taking a quantitative approach outweighs the benefits with describing the value of technologies in monetary terms.

Uncertainty and risk

Uncertainty and ambiguity are many times the underlying reasons for the difference in the performance, structure and survival of organizations (Petrick and Provance, 2005). In order to achieve market leadership, foresight into the trends that influences technological development and organizational adoption is required. Fast, accurate and comprehensive decision-making abilities are also a necessity.

Managing technology is about managing risk, as well as creating opportunities (Boer, 1998). If one focuses only on certainty it is difficult to create opportunities that can create value. It is easy to just believe that risk is a bad thing and to forget that a higher degree of risk also means a higher potential reward. Risk arising from new technology can be reduced by continued R&D efforts and investments but it is important to remember that risk can also be reduced by diversification; a portfolio of many high-risk projects are together less risky compared to a single high-risk project on its own.

These two kinds of risk are what Boer (2000) terms market risk and unique risk. Unique risk is the risk that the project will be a failure. The higher the unique risk, the lower the value of the project. To reduce this kind of risk a company can diversify its technology project portfolio. The logic here is that there is a higher chance that 1 project out of 100 will succeed than 1 out of only 5 projects. According to Boer (2000) the purpose of R&D activities is to systematically lower unique risk. Market risk on the other hand is related to market fluctuations, the cost of necessary resources or the price a company will be able to charge for its products for example. A higher market risk increases the value of an option. Another term for this kind of risk is market-volatility.

In order for the decisions that have to be made in uncertain environments to be successful, consideration of a broader range of inputs, more specified criteria of acceptability, as well as consensus regarding organizational agendas are required (Petrick and Provance, 2005). Similarly, Boer (2000, 2003) suggests that a risk-adjusted valuation of R&D projects can be accomplished through a combination of regular Net Present Value calculations together with Decision Trees and Real Options. By using decision trees the option to abandon the project will be incorporated into the valuation (Boer, 2003). By doing this R&D programs can be structured as a series of go/no-go decisions. The unique risk of a project can thus be quantified. Real options on the other hand deals with the market risk of a project (Boer, 2003). By real options it is simply meant the application of regular financial options methodology to business situations (Boer, 2000). The usefulness of the real options approach is that it puts value on managerial flexibility in a way that standard DCF methods does not. Boer states that this approach is suitable for "*situations with high risk, exposure to volatile* *markets, longer time horizons, and progressively increasing development costs*" (Boer, 2003, p. 51). All of these criteria are applicable to a technology project in an industrial setting.

Boer himself declares that this combined method is not useful every time and in all situations. When it comes to projects that are clearly very profitable, or conversely, projects that are obviously not profitable, it will not make any difference applying this methodology (Boer, 2003). The method will however be able to make a difference when deciding on projects that are 'close calls'. Projects with only a slight positive NPV, or even a small negative NPV, are the ones that will benefit the most from the real options approach to valuation.

Hunt et al. (2007) discuss the value of incorporating uncertainty in the form of probability estimates when performing valuations. Their conclusion is that explicitly including uncertainties in the calculation does not actually provide much new information, insights or extra confidence and can actually detract from the "storyline" by adding extra noise. A simpler approach, without many calculations and with uncertainties illustrated in words only, is easy to understand and can provide a common framework for the people involved. In other words, a relatively clear picture of the relevant scenarios can be established. Including uncertainties and more calculations in the model will create a more detailed picture but according the Hunt et al. (2007) this level of detail is most often not very accurate, nor is it necessary in most cases. The margin of error is large and a sensitivity analysis would blur most of the added detail by incorporating the uncertainties.

The main point that Hunt et al. (2007) are trying to make is that inserting extra unreliable information, in this case estimated uncertainties, into a coherent story will make the story less comprehensible, without adding any real additional information. This goes against Boer (2000, 2003) who takes the view that adding uncertainty will better enable companies to make better decisions regarding what actions to take based on the estimated outcomes from these decisions. Hunt et al. (2007) however agrees that using probabilities can be useful when they are credible and the structure of the underlying model is clear.

Roadmapping

Roadmapping has become widely accepted and is used in many settings, such as technology, strategy and product evaluation. It has its early roots in the US automotive industry, but it was championed by Motorola and Corning in the late 70s and early 80s (Probert and Radnor, 2003). The first paper on the subject is from 1987 and is concerning Motorola's use of roadmapping. Today many other various companies have adopted technology roadmapping and customized it to their specific needs. Examples from the literature include Rockwell Automation, Philips, Lucent Technologies, Domino Printing Sciences, and Royal Mail among many others (see for example McMillan, 2003; Phaal, Farrukh and Probert, 2007; Albright and Kappel, 2003; Phaal, Farrukh and Probert, 2003; Wells, Phaal, Farrukh and Probert, 2004). Figure2 depicts an example of a roadmap. In its basic form the rows, or layers, of a roadmap represent for example markets, competition, product platforms, technology, processes and various other aspects that are considered important to the business (Talonen and Hakkarainen, 2008). The horizontal axis simply represents time.

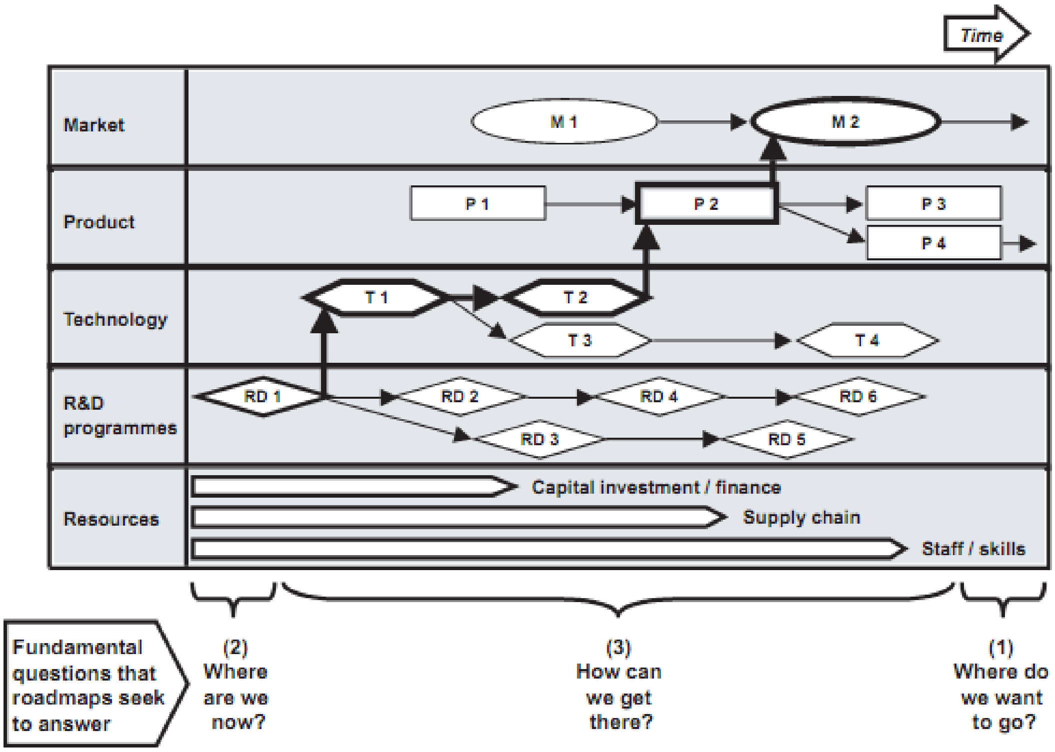

Figure 2. Example of a generalized multi-layer roadmap

Beeton, Phaal and Probert (2008) states that, in general, most authors focus more on what a roadmap *does*, i.e. its functional attributes, rather than what a roadmap actually *is* and that there is considerable diversity in the literature when it comes to what exactly constitutes a roadmap. Beeton et al. (2008) also quote Kappel (2001): "*defining what roadmapping means has become particularly challenging with the explosive popularity of the term, where all kinds of forward-looking documents are sometimes called roadmaps*". The main reason for the large diversity is the great variety of roadm0aps in terms of objectives, what issues are addressed and what techniques are used as well as the output format and the actual content of the output.

The general purpose of creating a roadmap is however, according to Probert and Radner (2003), to help a company to reach its goals, whatever they might be, and to help make sure that the organization has the required capabilities in place at the right time in order to achieve these objectives. In other words, when a group creates a roadmap they also create a common view about the future and what they want to achieve within that group. Roadmapping thus helps to facilitate communication by creating a common language and understanding of problems that the group faces. Another advantage offered by roadmapping is that it can allow for greater coordination across business units, departments, and even different companies in the same corporation. Strategies, product plans and technology plans are typically created independently by the people responsible for them, but by using a common roadmap these can become much more coherent (Albright and Kappel, 2003). This of course also leads to decreased costs and a reduction in unnecessary replicating work. Tolfree and Smith (2009) list some additional advantages that using a structured roadmapping process offers. These are, for instance, helping to incorporate new technology into a business and identifying new business and market opportunities and technology gaps within the company.

It is good practice to include persons from many different levels in the organization and from all aspects of the business when creating a roadmap (Tolfree and Smith, 2009). This builds on the assumption that people from different parts and levels in the company possess unique and valuable information (Petrick and Provance, 2005). The people in the organization with the most up-to-date knowledge of the company's technology component development, competing technologies and potential substitute technologies are most often found at the lower levels of the organization. Here the researchers and engineers who are working directly with technology development can be found. On the other hand, the people with the best knowledge of the company's resources and the market environment reside at the upper levels. In order to get a much broader perspective and be able to capture a complete picture of the situation in the roadmap it is thus necessary to include a variety of people from different positions within the company in the roadmapping workshop. People from marketing and manufacturing departments should ideally also be included.

Sometimes, especially when dealing with radical innovation, it can even be useful to include knowledge from outside the organization itself (Petrcik and Provance, 2005). These outside sources can for example come from suppliers, partners, customers and academia. At an individual level, information is incomplete and limited. A roadmap is meant to aggregate all these smaller pieces of information and produce a greater whole with a more complete picture of emerging issues and trends. This fits in well with Boer (2003), as discussed in the 'Technology Valuation' chapter above.

Roadmapping can thus be seen as a mechanism that provides a link between the strategic, executive level of decision making and the operational level (Petrick and Provance, 2005). It expands an individual business unit's ability to sense changes in the technology landscape by integrating the perspectives of experts from many different areas. Some of these areas may even be outside of the normal competencies of the business unit in question.

Talonen and Hakkarainen (2008) points out that roadmapping *does not* tell people where the company is going, as some people might believe. Rather, it is about *how* the company will get to where it is going. The actual goals that the company wants to reach need to be decided before the actual roadmapping process. This is in accordance with Probert and Radnor (2003). Hence, when done properly, roadmapping can "*serve as a foundation that enables a company to respond to varying customer demands*" (Strauss and Radnor, 2004, p. 53).

Roadmapping is very flexible and can be used for many different purposes, although the aim is generally to capture a high-level synthesized and integrated view of strategic plans in a simple graphical format (Phaal, Farrukh and Probert, 2007). Roadmaps need to be customized to the specific organization that it is to be applied in. There are because of this many different subtypes and variations of roadmapping in use. Phaal, Farrukh and Probert (2004a) have identified eight generic types of roadmaps, each used for a different purpose. These are:

1. Product planning
2. Service/capability planning
3. Strategic planning
4. Long-range planning
5. Knowledge asset planning
6. Program planning
7. Process planning

8. Integration planning

Out of these eight different kinds of roadmap type, the product focused roadmaps are by far the most widely used in the industry (Phaal et al., 2004a). Furthermore, Beeton et al. (2008) concludes that roadmapping can take on two distinct forms, exploratory or goal-oriented. Exploratory roadmapping deals with surveying potential future possibilities, while goal-oriented roadmapping is concerned with "*defining strategies to realize clearly defined future targets*" (Beeton et al., 2008, p.401).

The actual process of creating a roadmap is carried out during a workshop, or a series of workshops (Phaal, Farrukh and Probert, 2007). For example, the process for product-technology planning developed by Phaal et al. (2007) takes place during four half-day workshops with specific objectives for each day. It is important that participants come from as many functions, business units and levels within the company as possible. Participants can, for example, include representatives from development, marketing, manufacturing and financial departments. Phaal et al. recommend 8-12 participants in their product roadmapping workshops and 15-25 participants in the strategy and policy workshops (Phaal and Palmer, 2010). These workshops can in other words be seen as social events designed to bring together a diverse group of people in order to create a large experience and knowledge pool that is better able to deal with the problem at hand than any single individual (Kerr, Phaal and Probert, 2012). The key notion here is thus that the use of many viewpoints creates a foundation of higher quality for informed decision making compared to the judgment of a single person.

Questions that should be answered during the roadmapping workshop are according to Phaal and Palmer (2010):

- Where are we now? Where do we want to go? How can we get there?
- Why do we need to act? What do we need to do? How can we do it?

Tolfree and Smith (2009) also describe a roadmapping procedure that is very similar to Phaal and Palmer's. The four questions that according Tolfree and Smith need to be answered during a roadmapping workshop are:

1. Where are we now?
2. Where do we want to be?
3. What is stopping us getting there?
4. What needs to be done to overcome the barriers?

The only great difference between these authors is that Tolfree and Smith's fourth and final question has been divided into three separate but related questions by Phaal and Palmer (2010). Tolfree and Smith (2009) liken their four questions to the SWOT-analysis framework. Strengths and Weaknesses correspond to question 1 while Opportunities and Threats correspond to questions 2 and 3 respectively. Question 4 is aimed at creating potential actions that the company can take based on the three earlier questions.

The first step here is thus to establish the company's present situation, and to put this in relation to competitors. In addition, gaps that might exist in the product line or market areas should also be identified. Furthermore, market drivers and trends for the current topic should be highlighted since they will influence future technology requirements in a major way. Tolfree and Smith (2009) suggest that an appropriate tool to use in this stage is STEEP. STEEP stands for Social, Technological, Economical, Environmental and Political and is used to assess trends and drivers. Questions that could be asked during this stage include for example ‘Who are our present customers?’, ‘What are the current trends and drivers?’, ‘What are our niche areas?’ and ‘Is capital investment sufficient?’ (Tolfree and Smith, 2009).

The purpose of the second stage is to decide the organization’s aspirations and wants when it comes to new products, processes and services in the short, medium and long term respectively (Tolfree & Smith, 2009). It is important to remember that the goals should be ambitious but also not too unrealistic, as this can have a demotivating effect on people. The sorts of questions that one could ask are ‘What is our vision for the future?’, ‘Are we doing something that we should put more effort into or drop entirely?’ and ‘What new areas could we be working in?’.

The third step is simply to identify barriers that could stop the company from getting to where it wants to go. Relevant questions to ask in this stage include ‘What are the gaps in our technology?’, ‘Do we have the skills we need within the company?’ and ‘Do we have the necessary funding?’ (Tolfree and Smith, 2009). Finally, what is needed in order to overcome the barriers is mapped out in the fourth and final step (Tolfree and Smith, 2009). According to the authors this is the most important step to get right.

Phaal, Farrukh and Probert (2004a) conducted a survey regarding the challenges associated with implementing roadmapping. The three main challenges the respondents reported are keeping the roadmap process “alive” on an on-going basis, starting up the process, and developing a robust roadmap process for the company.

Drawing on the literature sources discussed above, a definition of what constitutes a roadmap has been constructed. The definition that will be used throughout this thesis is the following:

“A roadmap is a tool used to plan time, allocate resources and identify critical enabling and disabling factors in order to achieve a predefined organizational goal or survey potential future possibilities”

This definition includes the time scope that forms the basis which the roadmap is built around as well as what resources that need to be included and what critical factors that need to be considered in order to reach a successful completion of a project. The definition also incorporates both of Beeton’s et al. (2008) two types of roadmaps, that is, exploratory and goal-oriented.

Farrukh et al. (2009) writes that an important feature of technology development is that a technology evolves and matures. This forces continuous valuation efforts in a manner that is iterative. Thus, the authors propose a timeline for when different technology evaluation methods are most appropriate. This is shown in Figure 3. As can be seen in the figure Farrukh et al. (2009) supports the view that roadmapping, and specifically value roadmapping, is a suitable method to use when dealing with early stage technologies.

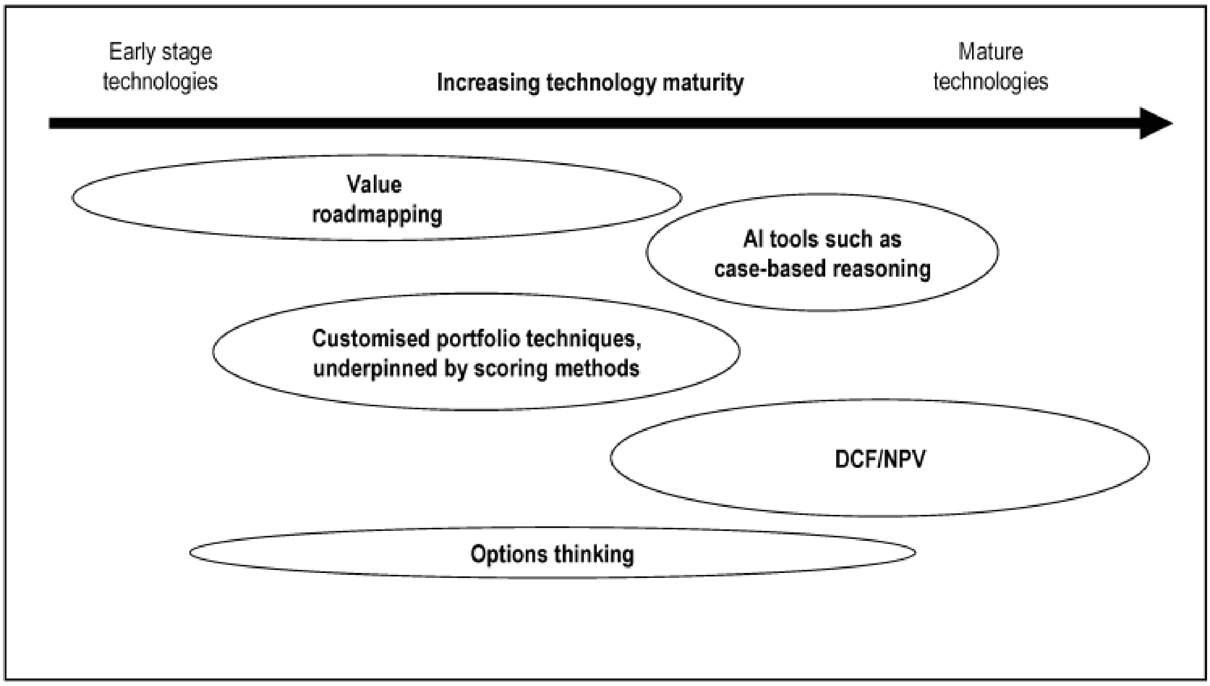

Figure 3. Farrukh et al.'s (2009) timeline view of approaches to technology valuation.

Value Roadmapping

Value roadmapping (VRM) is outlined in a paper by Dissel, Phaal, Farrukh and Probert (2009). It is a qualitative method based on the more regular technology roadmapping methodology and is mainly indented to address exploratory issues regarding the appraisal and evaluation of emerging technologies. According to Dissel et al. (2009) it can also be applied to later-stage technologies as well when investigating new applications. In other words, it is a method to explore and improve the value of a technology project at an early stage by linking current investment and decisions to longer term outcomes. Although it might not be possible to accurately predict the development and exploitation of a technology, VRM is built around the idea that the more detailed the picture, the higher the likelihood that the estimated value of the technology will be realistic. The authors also note that the VRM approach does not prescribe decisions or outcomes. Figure 4 provides an example, taken from Dissel et al. (2009), of what the architecture of a value roadmap might look like.

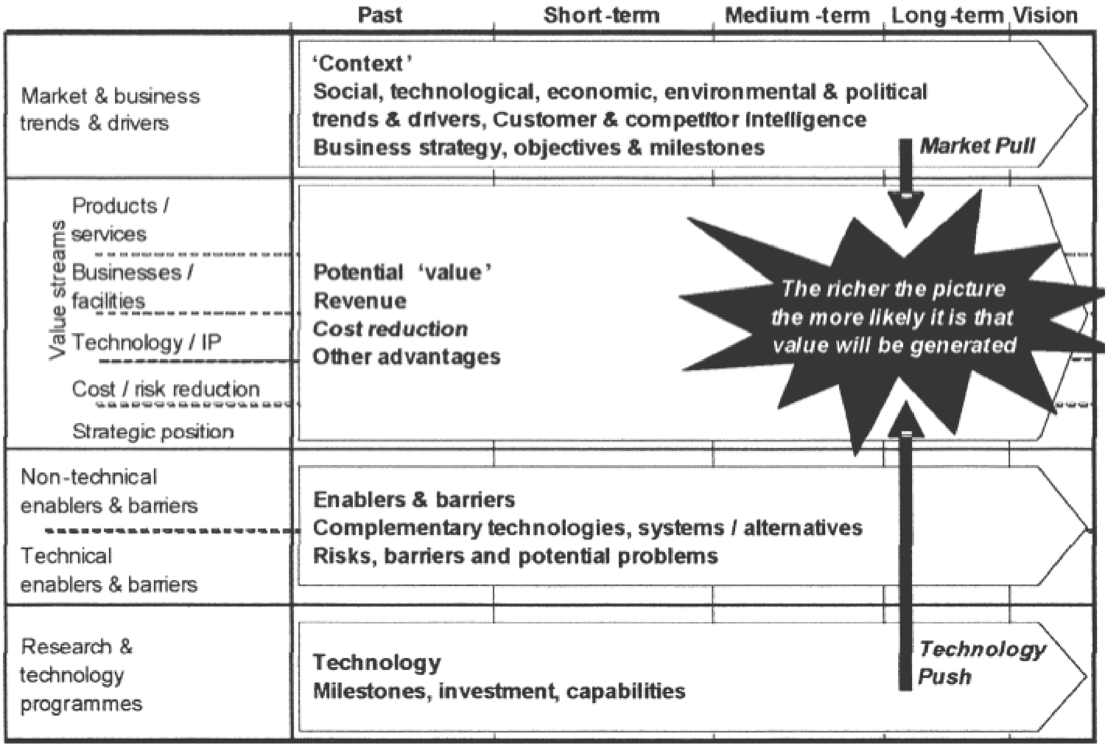

Figure 4. Value roadmap architecture according to Dissel et al. (2009).

The layers in Dissel's et al. (2009) VRM architecture are the following:

- *Market and business trends and drivers* – Drivers that focus on external market trends (for example social, economic, technological, political, environmental, and internal business factors). These factors influence the development of products and technologies in the areas of interest.
- *Value streams* – The sources of future revenue and savings (for example products, services, technology/IP, facilities, strategic position, and cost or risk reduction). All, except 'Strategic position', relate to the generation of cash revenue, or in Bowman and Ambrosini's (2000) terminology, exchange value. Strategic position on the other hand includes all non-financial factors that can provide a foundation for future generation of revenue.
- *Enablers and barriers* – Technical and non-technical challenges and risks as well as complementary assets or resources that are needed in order for the firm to be able to exploit the technology in question.
- *Research and technology programs* – Include existing and planned projects, future possibilities and competing and complementary technologies.

Another important feature of the VRM is the time-axis. It enables linking together the short-, medium- and long-term perspectives for all the layers in the roadmap architecture. It thus allows you to link the current technology investment with future expected revenues. Typically, the time-horizon of the VRM extends considerably farther into the future compared to a project plan (Dissel et al., 2009).

A VRM process is usually conducted as a workshop, or a set of workshops, involving people from both technical as well as commercial functions (Dissel et al., 2009). This is done in order to create an interdisciplinary discussion. The different steps in the value roadmapping process follow below, as they are described by Dissel et al. (2009).

Preparation phase

1. *Define strategic framework/vision/scenario* – The framework that "*governs the technology exploitation, including any overall assumptions, boundaries and constraints that apply*" (Dissel et al., 2009, p.49). The result is displayed on the right hand side of the actual VRM architecture. It is also important that both an owner of the VRM process as well as participants to the workshop are identified in this step.

Workshop phase

2. *Map technology development and investment milestones* – Participants map current and future potential technology, in terms of the technical capabilities that will be achieved at key milestones. The results are captured in the Research and Technology Programmes layer of the VRM architecture.
3. *Define value streams* – The goal in this step is to identify as many specific sources of potential future revenue and value as possible, based on the two previous steps, and then to prioritize them in order to identify the most interesting opportunities in the short-, medium- and long-term. Participants are encouraged to forecast or estimate revenue/value for each opportunity. Traditional methods for estimating value can be used, such as NPV. The limitations, as discussed above, of these valuation techniques should be kept in mind however and in some situations a rougher estimate of only the scale of the value streams can be more appropriate. This is especially the case for the more long-term technology development efforts.
4. *Map market and business trends and drivers* –Map the market and business trends and drivers that influence the prioritized value opportunities. Examples of such trends and drivers include social, economic, environmental, technological and political drivers, knowledge about potential customer needs and competitors, as well as the milestones and goals of the technology. The outcome is then mapped in the corresponding layer of the value roadmap architecture.
5. *Map barriers and enablers* – Both technical and non- technical barriers and enablers associated with developing and exploiting the technology are identified, as well as associated and/or complementary resources that must be in place in order for the technology development to succeed.
6. *Review project plan and VRM* – Compare the existing technology development project plan with the results of the newly created value roadmap to see if they match. Typically, the focus is on the key strategic business drivers of the firm.

After the workshop

7. *Present visualization* – Tidying up of the initial roadmap in order to make it more helpful in communicating key messages by developing additional summary or communication roadmaps.

Continuous work

8. *Maintain VRM as a process* – The VRM (and associated documentation) needs to be maintained on an on-going basis in order for the company to be able to gain all the benefits associated with the process.

These eight different steps from Dissel et al. (2009) are also presented in a summarised form in the graphic below.

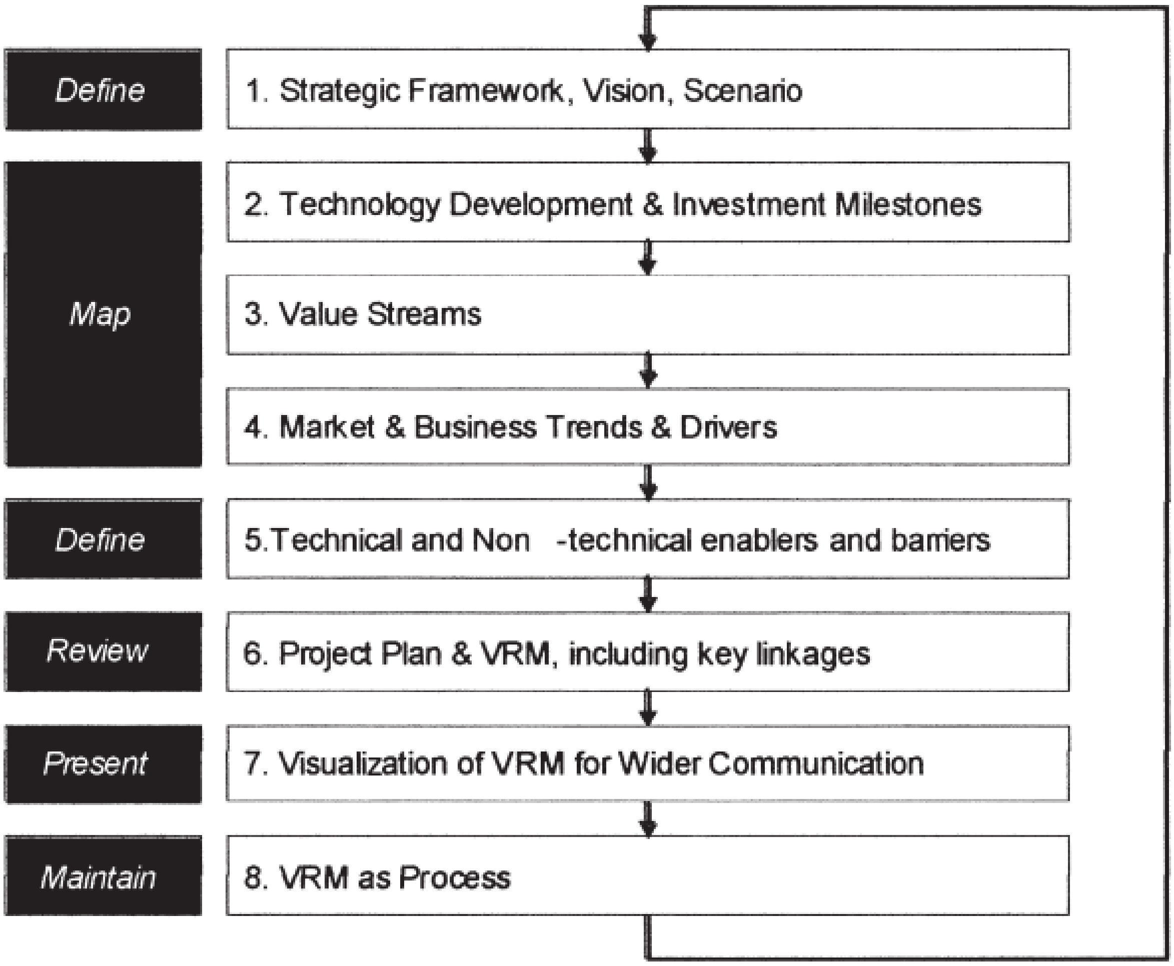

Figure 5. The eight steps of Dissel et al.'s (2009) value roadmapping method.

The definition of what constitutes a roadmap thus needs to be modified with the input from Dissel et al. (2009) in order to make the definition incorporate value in a more clear and better way. The new, modified definition is:

*"A **value based** roadmap is a tool used to plan time, allocate resources and identify critical enabling and disabling factors in order to achieve a predefined organizational goal or survey potential future possibilities, **and to identify and describe future potential value streams resulting from these activities**"*

The changes to the original definition are here presented in a bold typeface. As can be seen, the definition has now been broadened to include future potential value streams. These value streams can be described in two distinct ways, quantitative and qualitative. A qualitative approach would entail describing the value streams in detail in text, while a quantitative approach requires calculations to be made regarding the financial value of the technology in question. These calculations can for example be based on some kind of Discounted Cash Flow method.

Method

This chapter describes the approach that was used to answer the research questions and fulfil the purpose of the Master's thesis. It considers how data was collected and analysed and how the methods that were used affect the validity and reliability of the study. The chapter will end with a description of the workshops that have been conducted during the course of the thesis with the aim of testing the developed roadmapping method.

Research design

As mentioned briefly in the Introduction chapter above, the principal contribution to the scientific literature on roadmapping of this study is the development of a roadmapping method that is designed to explore the applications and usefulness of technologies and associated features during early lifecycle stages and what value these applications will create for the customer. The current literature describes many different kinds of roadmapping that are suitable to use in various situations but this is an area that has largely been left unexplored in the existing roadmapping literature. It is nonetheless a very important capability for companies to develop if they want to keep up with advances in technology and create a more balanced and valuable technology portfolio for the future.

Furthermore, most existing literature focuses primarily on 'technology push' with little consideration of 'market pull'. The roadmapping method developed during this thesis tries to remedy this low focus on market pull by putting a higher emphasis on the customer. For example by exploring what value a technology or feature will create for the customer and what customer needs a new feature can help to satisfy.

This research thus aims to improve the roadmapping process at Volvo Technology. A qualitative research strategy has been used in the study, which according to Bryman & Bell (2011) is suitable for theory generating studies. By studying the roadmapping process at Volvo, Tetra Pak and Ericsson it will be possible to identify differences and best practices. The findings at Volvo will be compared to the existing roadmapping literature. Benefits described in literature will be used for identifying problems and solutions to problems in the roadmapping process at Volvo. Roadmapping literature and case studies at Volvo, Tetra Pak and Ericsson are complemented with trial workshops in order to design and test a roadmapping process that to a larger degree utilizes the possible advantages of roadmapping compared to today's use of roadmapping at Volvo Technology. How the previously postulated research questions will be answered is discussed below:

1. *How is roadmapping carried out at Volvo Technology today?*

The answer to this question is based on the 27 interviews that where conducted around Volvo GTT. These interviews provided many different viewpoints and perspectives and offered insights into how roadmapping is currently carried out within the different business units and groups at Volvo. Thus, a case study of Volvo GTT's existing roadmapping process and content analysis of roadmapping documentation was carried out and then analysed in order to create an understanding regarding what roadmapping methods are practiced at Volvo Technology today.

2. *What are the main differences between how roadmapping should be managed according to literature and Volvo Technology's way of working with roadmapping?*

In order to answer this question, the data that was collected during the interviews around Volvo was compared to existing literature on the subject of roadmapping. Comparisons to the interview findings at Ericsson and Tetra Pak have also been made in order to identify differences in the three companies' way of working with their respective roadmapping processes. In order to identify existing problems at Volvo, the main benefits described in roadmapping literature was compared to the results from Volvo Technology's roadmapping.

3. *How should a roadmapping process for Volvo Technology be designed in order to take advantage of the roadmapping benefits described in literature?*

Existing roadmapping literature together with case studies at Ericsson and Tetra Pak were used to identify solutions and give recommendations on how to improve the roadmapping process at Volvo Technology. Based on these solutions and recommendations a new roadmapping method will be developed. In order to evaluate this new method it will then subsequently be trialled and tested in a series of workshops conducted at Volvo with suitable employees from around the Volvo Group as participants.

Literature study

In the first phase of the thesis an in-depth literature review was carried out in order to identify definitions and methods concerning roadmapping and assessment of technology value. Subjects that will be studied include the concepts of value and various forms of value like use value and exchange vale, value creation and various forecasting methods and different kinds of roadmapping techniques (i.e. Technology Roadmapping, Value Roadmapping etc.). In addition, literature on the valuation of technologies in uncertain environments will be studied.

For finding relevant literature, databases such as ProQuest and EBSCO Host were used. The databases were accessed through the website of the Chalmers library. In addition to this, some of the literature was found by using Google Scholar. Several sources dealing with the same topic were used in order to make sure that as many different viewpoints as possible were taken into consideration before any recommendations were made and conclusions drawn. Taking many different sources into account at the same time also helped to increase in the validity of the study.

In order to find more literature than the initial searches resulted in, the references of the reviewed papers and articles were checked. If a reference was deemed to be of relevance to this thesis it was also searched for and studied further. Literature recommendations and suggestions that are provided by interviewees during an interview session were also investigated.

Interviews

Two different kinds of interviews have been used, phone interviews and interviews in person. Interviews in person were preferred when possible. Of a total of 34 interviews, 29 were held in person and 6 over the phone. 27 of the interviews were with Employees at Volvo, 6 with Ericsson and 1 with Tetra Pak. The interviews lasted a usually lasted between 45 minutes and 1 hour. A few interviews lasted longer than this however. Voice recording was avoided in order to make the interviewee more comfortable and give more trustworthy answers. Instead, both interviewers wrote extensive notes during the interviews.

An interview guide was prepared in advance of the interviews during the early phases of the project. This was done with the aid of Bryman and Bell's (2011) recommendations on how to conduct a semi-structured interview. The interview guide consists of a list of questions that would help the interviewer cover all the areas of interest. Questions were designed to deal with broad areas and probing was used for getting further information. To investigate how the interview questions were interpreted by others, all questions were pretested on friends with relevant education for the topic. After the first interviews were completed the interview guide was updated in order for the questions to reflect the new information. Questions that were found to be irrelevant were also deleted and new questions were added to the interview guide. Furthermore, interview questions were dynamically adapted to the individual interview, depending on the role and knowledge of the person being interviewed. In a few cases not all of the questions on the interview guide were asked since all questions were not appropriate for that particular interviewee and his or her role within the company. The final interview guide can be found at the end of the report in Appendix A. The questions are in Swedish.

Topics that the interviews covered included, for example, what people that were responsible for building roadmaps; what people participated in building roadmaps; how the on-going projects were communicated between departments; how the value of new technologies was calculated and communicated; what criteria's technologies must fulfil in order for them to be of interest for further development; how Volvo try to ensure that a project actually will generate use value for the customers; what problems and challenges they have faced with the current roadmapping process; what the interviewee see as integral parts to a good evaluation of a technology and what parameters they would like to see included in a new roadmap method. Later interviews also covered how the cooperation between Volvo Technology and 3P works and the linkages between the two.

The initial interviews were conducted with the Technology Area Directors at Volvo Technology. They were asked to recommend other employees to get in touch with. A so called 'snowballing' approach was hence taken to obtain new interviews. In other words, after each interview the interviewee was asked if he or she knew of any additional people that could be of interest to the study. These interviewees were in turn also allowed to recommend even more employees as potential new interview subjects. The limit for how many interviews to conduct was set to when we as interviewers could reasonably predict in advance what an interviewee's answer to any particular question would be. To ensure that data were interpreted correctly both of the authors were present for all of the interviews. Both interviewers also asked questions and took notes during the interviews.

The interviews tended to become more open as the study progressed and more interviews had been carried out. When we as interviewers became more and more familiar with the topic it became easier to formulate relevant questions during the interview without being led by the interview guide. The interview guide was thus, in the later interviews, not as strictly adhered to as in the early ones. Apart from these exceptions, the interviews were conducted in a similar manner in order to facilitate an easier comparison between the different interviews.

Interviews will, in addition to the Volvo Group, be conducted at Ericsson and Tetra Pak. Ericsson and Tetra Pak will be used to provide more information about how the roadmapping process can be organized and for identifying effective ways of working with roadmapping. The interviewees' answers will be analysed and used as input data when building the technology valuation method.

Tetra Pak and Ericsson will in other words be used as reference in order to build 'best practice' understanding of the subject.

The conclusions that are drawn from the conducted interviews, coupled with the existing literature, will be used as the foundation when designing the customized architecture of the value based roadmap and the workshop. It will also form the basis when deciding what focus the roadmap and the workshop will have. This, since the roadmap needs to deal with the previously identified problems and issues in order to maximize its usefulness for Volvo Technology when it comes to the valuation of early-stage technologies. In addition to this, the information provided by the interviews will also be of importance when answering the research questions of the study.

Analysis

In the analysis, the empirical results will be compared to the theoretical framework in order to answer the research questions. Grounded theory will be used as a tool when analysing the interviews. As described by Bryman and Bell (2011) data will be coded and mapped into categories, data collection and analysis will proceed in tandem and refer back to each other. While running the workshops participant observation will be used and the participants will be interviewed in order to to generate feedback and find weaknesses with the developed method.

The study will result in a new roadmapping approach for Volvo that is designed for exploring the uses and value of technologies in early life-cycle stages. This method will be tested by conducting a series of workshops. The process and the workshops will be based partly on existing literature and partly on the result of the interviews that will be conducted at various business units within the Volvo Group. Input from the companies Ericsson and Tetra Pak will also be considered. The outcome of these workshops will then be analysed in order to improve the method further. Recommendations of actions to consider when designing, organizing and implementing the roadmapping process will lastly be made. The intention is thus to create a new way of working with roadmapping at Volvo Technology and to maximize the usefulness of the roadmapping process.

Reliability of the study

The reliability of a study tells whether the same result can be expected if the study is replicated (Bryman and Bell, 2007). Documentation of all the different steps performed in the research will thus improve the reliability of the study in question (Yin, 2003). Reliability can be divided into stability, internal reliability and inter-observer consistency. Stability considers whether the result is stable over time while internal reliability is a way to measure if the indicators are consistent and the scores on one indicator relate to the scores on other indicators. The inter-observation consistency of a study tells whether the researcher is consistent in the classification of data and, if there are multiple researchers, to which degree the researchers' data classification differ from each other (Bryman and Bell, 2007).

Similar to reliability, but a more suitable way of measuring to what degree a research study is replicable when it comes to qualitative research, is dependability. To establish dependability Lincoln and Guba suggest that the researchers shall keep complete records of all phases in the research. (Lincoln and Guba, 1985, discussed in Bryman and Bell, 2007).

In this research the different steps in the study are described and documents as interview guides are attached in appendices in order to increase the reliability. However, there have been less formal activities during the study, for example mail conversations and informal discussions that also have influences on the result, which can be hard to replicate. The study is to a high degree possible to repeat for other researchers, the same interview guide can be applied to the same sample for example. However the social context in which the research was performed in is, as described by Bryman and Bell (2007), dynamic and will change over time.

During the research a large organizational reorganization was on-going at Volvo. This will have a negative effect on the stability of the study. Further the interview guide was not followed strictly after the researchers became comfortable with the topic and could follow up answers by asking questions outside the interview guide. Hence a similar result can be expected if the same research is performed within a short time period after the initial research.

Validity of the study

Validity reflects whether the indicators used really measure the concept under study while the external validity of a study measures to what degree the findings can be applicable in other settings than the one where the research was performed. External validity in qualitative research is generally low (Bryman and Bell, 2007). It is hard to draw general conclusions about the roadmapping procedures based on qualitative data since this might be unique for the organization in question.

Instead of external validity, Lincoln and Guba suggest that transferability is more suitable in qualitative research. A thick description increases the transferability and can provide other researchers with a rich picture that can be used as a database for making judgments regarding what findings might be suitable for another specific setting (Lincoln and Guba, 1985, discussed in Bryman and Bell, 2007). In order to increase the transferability of this study, relatively detailed descriptions of the different cases are provided. However the external validity, or transferability, can be considered to be low to medium in this study.

Credibility reflects how the study handles different responses depending on the aspect of social reality (Lincoln and Guba, 1985, discussed in Bryman and Bell, 2007). To increase the credibility the research has been conducted with reasonable care and triangulation have been used when possible. Different data sources that have been used for triangulation are interviews at Volvo, Tetra Pak and Ericsson, roadmapping documents at Volvo together with scientific papers.

Testing of the roadmapping method

Three workshops have been conducted during the course of the thesis. Table 1 provides a quick overview of these three workshops and each of them will be discussed in more detail in the following sections of the report.

Table 1. Overview of conducted workshops

No.	Topic	Number of participants	Participants' work location	Time
1	Electric vehicles (Pre-test)	4	4 VTEC thesis workers	1 hour
2	Wireless sensors, increased up-time and maintainability	8	3 VTEC, 2 Product Planning, 2 Volvo Powertrain, 1 Advanced Engineering	1,5 hours
3	Augmented reality, increased up-time and maintainability	8	3 VTEC, 2 Volvo Parts, 2 Sales and Marketing EMEA, 1 Volvo IT	2 hours

Workshop objectives

The objectives are inspired by the literature in regards to common and already established and tested goals for roadmapping workshops. Of course, they are also heavily influenced by findings from the interviews regarding the needs of Volvo as a company and what is currently missing from its roadmapping processes. Even though the workshop structure can be applied to many different technological fields and areas the workshops themselves have the same objectives and general goals in common. The primary and secondary objectives of the workshops are the following:

Primary objective:

- Align people by creating and/or reviewing a common development roadmap, for both the long and short term, by identifying and communicating critical features and technologies and in what ways these can add Use value to the product offerings.

Secondary objectives:

- Enable different departments within Volvo to provide feedback and input into each other's projects.
- Establish and/or strengthen personal networks between business units.

The roadmaps resulting from these workshops will thus be of an exploratory nature in Beeton's et al. (2008) terms since the roadmap focuses on the uncertain future and potential ways to add Use value for customers to current and new product offerings; not on how to reach already defined and clear targets in the future, as would have been the case with a goal-oriented roadmap and workshop.

Workshop 1 – Pre-test, Electric vehicles

In order to pre-test the developed workshop structure and the roadmap architecture a test workshop was arranged with four other thesis workers at Volvo Technology. The purpose of this exercise was in other words to perform an initial test of the roadmapping method and to get valuable feedback on what could be improved and changed in order to make the workshops run more smoothly and become more focused. The actual output from the workshop was hence not important in this pre-test; it was the use of the actual method that was of interest.

The roadmap architecture that was used during this workshop was different from the one that was settled on after the workshop had been completed. This roadmap architecture can be found in Appendix C at the end of the report. The main difference lays in the fact that a fifth roadmap layer was part of the architecture at this stage. The layer was called 'Market trends and drivers' and was intended to provide background information and set the overall framework for the workshop. The intention was that the Product Planning department would provide an already completed PESTEL-analysis (Political, Economic, Social, Technological, Environmental and Legal) of the area in question for this step.

It was decided to remove the step 'Market trends and drivers' from the roadmap after completing the pre-test workshop and having discussions with future participants of the other two workshops. This step was intended to provide participants with background information and set the frame for the workshop. The step was however deemed to be quite unnecessary because of the fact that the participants would know most of the things in this layer of the roadmap already.

The 'Market trends and drivers' step was thus considered to not be very helpful and to just take time from the other, more relevant, parts of the workshop. Furthermore, the existing PESTEL-analysis was considered to be of a too general nature, by the Product Planning department, to be useful in this situation. It does not deal explicitly with the feature areas, maintainability for example, by themselves. Another reason for removing the step is that many things that would be in this layer can be rewritten to fit into the 'Enablers and Barriers' layer instead. This way, it can be ensured that no important information is missed while still keeping the workshop shorter and more focused on what is essential.

The pre-test workshop was one hour long and the chosen topic was 'Electrical vehicles'. The shorter time limit was decided on in part due to a lack of time for the participants and in part due to the lack of deeper technical knowledge of the field in question by the participants. A longer and much more detailed workshop would thus not have made much sense, not given any better results and would only have wasted the time of the participants. The actual workshop was followed by a review and feedback session lasting approximately half an hour.

At the start of the workshop the aim of the exercise was quickly described to the group of participants. After that, a short brainstorming session was held in order to identify future market trends and drivers. This was necessary since the Product Planning department's PESTEL-analysis was not available. The drivers were written down on sticky notes and after the brainstorming session had concluded they were placed on the first level on the roadmap architecture. Some important trends and drivers had also been prepared in advance by the facilitators in order save time for the rest of the workshop. After the sticky notes had been placed on the roadmap a facilitator read the notes aloud and if something was unclear it was explained by the person who had written the note in question.

After the first step the workshop continued with the ‘Wanted features’ step. Here the participants were asked to list features of electrical vehicles that are currently under development or evaluation and that they believe a customer to Volvo would want in the future. The features were written down under silence by each participant on sticky notes. As in the previous step, the sticky notes were placed on the roadmap, read by a facilitator and clarified when needed. Some features that the facilitators deemed important had also been prepared in advance of the workshop. These were presented after the participants’ sticky notes had already been placed on the roadmap. This was done in order to complement the existing ideas and to ensure that an important feature were not overlooked. Many of the sticky notes had similar features written on them. These notes were clustered together in order to reduce the clutter on the roadmap. Many smaller features were also listed. The result was that four main features were identified and it was decided that the rest of the workshop should focus on these four main features in order to not make the workshop and roadmap overly complicated.

The next step, ‘Required Technologies and R&D’, was skipped in order to save time for more important aspects of the workshop and also because of the previously mentioned lack of knowledge regarding the underlying technologies of all the features. The ‘What creates Use value’ step was instead started. Here the group of four split into two subgroups with two persons in each group. The groups were then tasked to discuss what Use value could be added for the customers by each of the four main features that were identified in the previous step. As before, ideas were written down on sticky notes. However, this time a new approach was tested when it comes to putting the sticky notes on the actual roadmap. This time one person from each of the two sub-groups put one sticky note on the roadmap at a time. The main difference however was that after a stick note had been put on the roadmap, the participant who posted it also read the message out aloud and explained in a little more detail what was meant by the text.

As with ‘Required Technologies and R&D’, the rating and prioritization stage was left out. It was felt that doing this would not be worthwhile and would not provide any additional useful input to the development of the roadmapping method. However, a discussion about various forms of voting and rating techniques was held in its stead. This discussion resulted in a few interesting new viewpoints and suggestions regarding how to facilitate a voting and prioritization process. Examples of things that were discussed are if the voting should be public or private, and how to best make it private in that case, and if the voting should be on all of the identified features or if the features that are absolutely necessary should be exempt from the voting since they have to be developed either way.

The ‘Enablers and Barriers’ step was also skipped. It was decided that it was better to extend the discussion and feedback session after the workshop rather than performing another step in the workshop process. This step is similar in nature to those already performed and would thus not have added much to the following discussion.

Learnings and feedback from the pre-test workshop

As mentioned above, after the actual workshop had been concluded, the participants were asked to criticize the methods used and to give feedback as well as suggestions about what to do differently and what to improve. Many important points were raised and a lot of valuable feedback was given during this discussion. We as facilitators also noticed things during the course of the workshop that could be handled differently and be done in a better and more efficient way in a future workshop. Some of the most important points are described below.

One of the most important findings is that the roadmap tends to quickly become fairly cluttered, even when similar sticky notes have been clustered together. This makes it hard to get a god overview of the roadmap and to draw clear linkages between the notes on different levels of the roadmap. This problem was also discussed during the feedback session and a few ideas about what to do in order to solve the problem was presented. One idea was to first post the sticky notes on a separate sheet of paper first before putting them on the actual roadmap. This could for example be a layer of the roadmap architecture placed on the table. Doing this will enable an easier clustering of notes as well as combining very similar notes into one. The facilitators then move the sticky notes from the first sheet of paper and place them on the same place on the actual roadmap on the wall.

Another problem that was noticed during the workshop was that it was hard to know exactly what features to continue to work with, since there were so many smaller, less important, features listed as well as many that were fairly similar to each other. The problem is in other words to focus the work in order to put more effort into the evaluation of the more important features. This connects to the problem discussed in the previous paragraph and the potential solution presented there might also help mitigate this problem to a certain extent. It is possible however that this problem was much more pronounced during the pre-test workshop since the participants were thesis workers with limited knowledge of the field and topic in question. In a workshop were the participants are experts within their field the situation might look very different. Specialists at Volvo naturally have a much higher understanding of the field, as well as knowledge about exactly what features and technologies are being developed and evaluated around the company. This can accordingly lead to a much higher level of structure from the beginning and, as a consequence, a much more ordered roadmap.

The actual 'Enablers and Barriers' step was, as previously mentioned, skipped during the pre-test. It was nonetheless discussed with the participants after the workshop had been concluded. Some participants felt that it might be better to move this step to an earlier timeslot within the workshop. When 'Barriers & Enablers' is placed at the end of the workshop it feels somewhat unconnected to the rest of the points and as something extra that is just attached to the workshop without much real meaning. It is believed that the rating and prioritization stage marks a much better and feels like a more natural conclusion to the workshop and that it feels forced to begin something entirely new after the voting stage has been concluded. This was the case when 'Enablers and Barriers' was located after the rating step. It has thus been decided to move 'Enablers and Barriers' to the position before 'What creates Use Value?' in the workshop guide in order to better integrate this step into the workshop as a whole.

The 'What creates Use value?' step was also moved after the trial workshop. In the final version of the workshop guide it is the second step in the process, not at the end of the workshop as in the workshop guide used at the trial workshop. At the new position the 'What creates Use value' step make it more clear that it is the Use value that the new features will bring with them that is of interest, not just the value of the individual underlying technologies for example.

Many other smaller issues and points to keep in mind in order to improve the coming workshops were also raised. These were mostly of a more minor character and are thus not discussed in any great detail. Instead they are presented in the list below in no particular order of importance.

- Clearly communicate the agenda, the goals of the workshop, what the expected outcome is, and how the workshop will be followed-up in the introduction at the start of the workshop.
- Potentially have the agenda for the workshop visible during the whole workshop.
- Use sticky notes in different colours for each level of the roadmap architecture in order to make it easier to distinguish between the layers and to know what sticky note belongs to what layer.
- It is better if the facilitators stand up when they talk.
- Leave time for discussions but cut them off when they start to go off topic in order to focus on completing the roadmap and keeping the workshop within the allotted timeframe.
- Discuss at the end if there was something new that showed up during the workshop.
- Decide on how to digitalize and save the roadmap in advance of the workshop and communicate this to the participants.
- The participants felt that the best way to present and post the sticky notes on the roadmap was the second method that was tested, i.e. notes are posted one at a time by their respective author and then read aloud and explained in a little more detail by the author himself.

Workshop 2 – Wireless sensors, increased up-time/maintainability

This was the second workshop that was conducted during the course of the thesis. The wireless sensor topic of this workshop and the maintainability and up-time focus was decided in collaboration with Volvo Technology. Some suggestions of people to include in the workshop were provided by Volvo. Besides these suggestions, some other potential participants were also identified based on their area of expertise and business unit. In total 12 participants had accepted to come to the workshop in advance. Not all of these 12 people showed up however.

There were in total 8 participants that attended this workshop and the participants came from four different business units within Volvo, Volvo Technology, Advanced Engineering and Product Planning at Volvo 3P, and Volvo Powertrain. Two are working with Electrical and Electronics Hardware at VTEC; these are the ones who have been involved with the actual development of the sensors in question. One is a Technical Leader of Electrical Components at the Advanced Engineering department. One is a Feature Specialist of Maintainability at the Product Planning business unit and is working with product strategy when it comes to maintainability. Two are working with sensor and component development at Volvo Powertrain. And finally, one is the Product Manager of Electrical/Electronics at the Product Planning department. In addition to these seven, our supervisor at Volvo Technology also participated in the workshop.

The time that was set for the wireless sensor workshop was one and a half hours, between 10.30 and 12.00. This shorter time was decided on due to the difficulty of coordinating a time where all of the intended participants were available and could attend the workshop. Four days in advance of the workshop a short description of what the new wireless sensors can do and what the associated challenges are were e-mailed to all of the participants together with the workshop guide and roadmap architecture. This was done so that the participants could prepare themselves better and to make the actual workshop run smoother. The background material and information about the sensors had been provided by Roy Johansson.

The workshop began with a short introduction to the topic, what the aim of the workshop was, and what the participants were supposed to do during the workshop. A very brief background presentation of the Master's thesis was also given during the beginning of the workshop. The introduction phase took roughly 10 minutes in total. After this, the actual workshop got started and the participants were put to work. The first task was, as described in the Workshop Guide in Appendix B, to list existing and potential features that either are currently being developed, or might be developed in the future. The participants were given approximately 15 to 20 minutes to complete this task and afterwards they posted their sticky notes on the roadmap architecture. A facilitator then read each of the notes in turn and grouped similar notes together. Less clear notes were also explained by its author to the rest of the group. Discussions within the group regarding the suggested features also took place during this phase. This was a very time-consuming process and around 30 minutes was needed to complete this step of the workshop.

This meant that the workshop was running late, and together with the shorter timeframe, it was decided to cut some steps from the workshop. This was done in order to be able to complete a few steps properly, rather than only half-finish all steps. The two steps that were cut were 'Required Technology and R&D projects' and 'Enablers and Barriers'. This meant that it was approximately half an hour left to compete 'What creates Use value?' step and the prioritization of the features.

For the 'What creates Use value?' step the group divided into two teams of four. Participants who came from the same business unit were split-up and put into different teams in order to facilitate a cross-functional discussion among the team members. The participants were in other words divided in such a way as to create as varied subgroups as possible. The two teams were then tasked to come up with ways in which the previously listed features could create Use value for the customers. One team were assigned the current and the short term features, while the other was assigned to work on the features in the medium term. No features were listed for the long term during the workshop. The participants had 20 minutes to complete this step.

The two next steps in the workshop were as stated previously skipped due to a lack of time. This means that after the listing of the various ways in which the features can create value the 'Rating and prioritization' phase began straight away. The teams had some time to study each other's sticky notes before the actual rating process was started. The participants gave points to the different features that they thought would create the most value for the customer. In this way the features were ranked in order of what potential the participants saw in them. The voting process is described in more detail in the Workshop Guide in Appendix B. The facilitators summed-up all the individual votes for the different features and presented the final voting scores to the group. This was the last step of the workshop and after it was concluded the workshop ended.

Workshop 3 – Augmented reality, increased up-time/maintainability

This was the third workshop to be conducted during the study. Once again, the topic and the focus on the area of maintainability and up-time for the workshop were in collaboration with Volvo. One reason for the maintainability and up-time focus was that it is the one out of three different areas that have received the least amount of attention at Volvo so far when it comes to Augmented Reality. Another reason is that focusing on the same area for both the wireless sensor workshop and the Augmented Reality workshop will create some synergies as well as facilitate an easier comparison between the two workshops.

For this workshop, some suggestions for possible workshop participants were provided by Volvo. One of these persons also offered a few suggestions of other possible participants. The rest of the participants were, as before, identified based on their current work position, area of expertise and what competencies we deemed necessary to include in the workshop. This resulted in a total of 8 participants from four different business units for the Augmented Reality workshop.

The manager for Simulation and Testing at Volvo Technology, that is a specialist of Augmented Reality, was one of the participants to the workshop. Another participant who has worked a lot with Augmented Reality is a Business Innovation Manager at Volvo IT's Tech Watch & Business Innovation department. One participant works with Systems and Architecture at VTEC and has a lot of experience working with up-time as well as some experience with Augmented Reality. Two participants are Customer Business Analysts at Volvo Parts and have experience with maintainability and after-market issues. Two participants came from Volvo Group Trucks Sales & Marketing EMEA. These two are from the same business unit where they work as Maintainability Managers within Service and Repair. These two participants accordingly have a lot of knowledge and experience when it comes to the actual service workshops where repairs and service of vehicles are performed and the layout and design of these service workshops as well as other after-market issues. In addition to these participants our supervisor at Volvo Technology, Daniel Lexén, also attended the workshop. Regrettably, the person working with maintainability and service workshops at the Product Planning business unit was unable to attend the workshop and had to cancel his attendance in advance of the workshop.

Together, the participants at this workshop consequently have a wide range of experiences and knowledge of different fields and areas. This cross-functionality is something that is described in the literature as being key when producing successful output at a workshop. We have thus strived to include as many different business units and departments as possible for this workshop in order to increase the level of cross-functionality as well as to be able to test and evaluate the roadmapping method in a real situation.

This workshop was two hours long, 08.30 to 10.30. It was thus one hour shorter than our initial estimation of three hours as the timeframe for the workshops. Similar to the previous workshop, a short description of what Augmented Reality is, what it can do, and what the associated challenges are were e-mailed to all of the participants together with the workshop guide and roadmap architecture three days in advance of the workshop. This was done so that the participants could prepare themselves and to make the actual workshop run smoother. The background material about Augmented Reality was compiled by VTEC's augmented reality specialist.

As in the previous workshop, this workshop also began with a brief introduction to the topic and what the aims of the workshop would be. A short background presentation of our Master's thesis was also given during the beginning of the workshop. After this all of the participants got a chance to give a short summary of who they are and what they work with at Volvo. The introduction stage took roughly 15 minutes.

The actual workshop then got started with the “Wanted features” step. This step was handled a little differently compared to the second workshop. As before, the participants got some time to first brainstorm features but instead of writing all of their ideas down and then post all of their notes at once, participants were encouraged to only post a few notes at a time and present the message of the notes to the group at the same time. This was done in order to facilitate a better discussion and decrease clutter on the roadmap due to many similar sticky notes. In total this took around 45 minutes to complete.

The next step was to come up with ways in which the previously listed features can create Use value for the customer. As in the previous workshop the group split into two teams of four persons each. The teams were designed to be as cross-functional as possible. One team was assigned to work with the current and short term features, while the other team worked with the medium and long term features. This was done in about 30 minutes. The “Required Technology and R&D projects” step started right after the value step. In this step of the workshop the aim is to try and identify technologies and projects that need to be finished in order for the associated feature to be developed. The participants stayed in the same two teams as before for this step and worked with this phase for approximately 20 minutes before the rating process was started. Due to a lack of time the “Barriers and Enablers” step unfortunately had to be skipped in this workshop as well.

The rating process was conducted in a similar fashion as in the wireless sensor workshop. First the participants had some time to read through the other team’s notes and then each person wrote down his or her points on sticky notes and distributed them on the roadmap. The facilitators then counted all the points, summed them up and presented the results to the group. After the workshop a discussion about the outcome was held before the workshop was finally concluded.

Empirical findings

This chapter of the report will present the empirical findings of the study. The findings are summarised in two tables. A more in-depth description of the interview findings are attached in Appendix D.

Interview findings

Tables 2 and 3 have been constructed to give a quick overview of the findings from the interviews that are described in Appendix D. Table 2 provides a summary of the key findings and differences when it comes to roadmapping at the three companies where interviews have been conducted, Volvo, Ericsson and Tetra Pak. Table 3 on the other hand shows only the findings at Volvo and the associated problems that have been identified with Volvo's roadmapping process. It is believed that implementing the developed roadmapping method can help to solve these problems.

Table 2. Summary of interview findings

Parameter/Company	Volvo	Ericsson	Tetra Pak
Roadmap structure	No standardized structure for creating roadmaps except when Volvo's roadmapping software 3RM is used. Most common is that each technology specialist develops their own PowerPoint templates	Standardized PowerPoint templates in use	Standardized structure
Tools used	Mainly PowerPoint but Volvo's roadmapping software 3RM is used at some places	PowerPoint. The tool Agilo is used for building backlogs.	Aris, a project planning software customized to fit Tetra Pak's roadmapping needs
Updating interval	Once a year	Once a quarter	Larger cross-functional workshop once a year, smaller updates by "core teams" continuously
Number of persons involved in workshop	One or a few persons from the same group/department creates and updates roadmaps	Smaller workshops, larger customers can sometimes be involved in the roadmapping process	Large workshops with both technical and commercial competences represented
Focus of roadmap	To plan technology development and R&D projects	Product focused roadmaps used for communicating new product features, both internally and externally to customers	Planning the technology development, research projects and investigate and document business impact of new technologies as well as competitor analyses
Time horizon of RM	Up to 25 years	12-18 months	Up to 10 years

Table 3. Overview of identified problems at Volvo

	Volvo	Problem
Roadmap structure	No common structure for creating roadmaps except when Volvo's roadmapping software 3RM is used. Most common is that each technology specialist develops their own PowerPoint templates	Lack of coherence, hard to compare and link roadmaps together and to get an overview
Tools used	Mainly PowerPoint but 3RM is used at some places	No common PowerPoint template. 3RM not widely adopted, overly complex and hard to use
Updating interval	Once a year	
Number of persons involved in workshop	One or a few persons from the same group/department updates the roadmaps	Does not help to spread project information to other departments. Commercial aspects are missed
Focus of roadmap	Plan technology development and R&D projects	Lacks market and customer influences, hard to question the use value of on-going projects
Time horizon	Up to 25 years	

Analysis

In this chapter the answers to the three research questions that were posed in the beginning of the report will be given. The answers will be presented for one question at a time, starting with the first. The answer to the third research question is quite extensive as it includes a description of the roadmapping method and workshop that was developed during the course of the study.

Research question 1

The first research question that the thesis aimed to answer is, as stated in the beginning of this report:

1. *How is roadmapping carried out at Volvo Technology today?*

A commonality between the departments, building roadmaps, is that senior management requires roadmaps to be made, updated and presented to them at least once a year. This is what initiates an update or creation of a roadmap. Except for communicating and reporting to senior management, the roadmaps are mainly used to show the on-going work locally at the department.

Technical specialists at the different R&D departments are responsible for creating and updating roadmaps within their technology area. A Roadmap for a certain technology is created locally at the department responsible for the technology in question. Most roadmaps are constructed in a meeting by a few technical specialists together and in some cases by only a single specialist working alone building the roadmap in a PowerPoint document. Only one interviewee talked about having participated in a workshop, with around 14 participants, aimed at developing a roadmap. This was however not an example of a cross-functional workshop; the workshop described by the interviewee included only participants from one department.

In general the roadmaps tend to focus on one technology and the technological development required in order to develop the technology further and be able to deliver certain features. The result is stored as a PowerPoint. This means that the roadmaps are only dealing with the development and technical viability and characteristics of a technology, feature or system, and not the potential value or usefulness to a customer in the future.

One of the major findings during the interviews is that there is no established coherent or common method for carrying out roadmapping work at Volvo today. Since there is no companywide structure in place most units have their own way of working when it comes to roadmapping. Some effort has been made by the former Volvo 3P in order to deal with the lack of a common roadmapping method in the company and the lack of linkages between different roadmaps. A web-based tool called 3RM has thus been developed with the aim of creating a system that will link roadmaps, projects and underlying technologies together. 3RM is used to create many, but not all, roadmaps at 3P and it is also used sporadically elsewhere within Volvo. It is very far from ubiquitous however and many people are not happy with this tool since they find it unnecessarily complex and hard to use. Most groups around Volvo Group Global Trucks Technology have thus chosen to create and use their own version of a roadmapping method. The far most commonly used tool around the company to make and save roadmaps is Microsoft PowerPoint. This has led to most groups having no linkages between their roadmaps and the roadmaps of other groups, usually they are not even linked within the own group.

We can from the above see that the answer to the first research question is that there is no real structured or organized roadmapping process in existence at Volvo Group Trucks Technology today. Roadmapping in the company is in other words characterized by a lack of structure and is more or less handled in an ad-hoc manner by the person, or persons, who are responsible for the development of a certain technology and hence the development of the roadmap for the technology.

Research question 2

The second research question of the study is:

2. *What are the main differences between how roadmapping should be managed according to literature and Volvo Technology's way of working with roadmapping?*

The lack of structure in the roadmapping process and locally managed roadmaps at the R&D departments makes it very hard to get a complete overview of exactly what is being worked on and how it is connected to all the other existing projects, product features or underlying technologies. Similar roadmaps of the same technologies focused on the same properties can exist at different departments within Volvo due to the lack of overview. This means that the same work is carried out in parallel at different locations without anyone taking notice. Since each roadmap is developed locally it is hard for others to get knowledge of what technologies are developed and where they are developed. There is also an absence of common framework and method within Volvo for creating and maintaining roadmaps which creates a problem of fragmentation and lack of coherence. Because of this there is no uniformity among the roadmaps and they cannot be compared and linked easily. Unlike an unstructured roadmapping process Tolfree and Smith (2009) mean that a structured roadmapping process can for instance, help to incorporate new technology into a business and identifying new business and market opportunities, fill technology gaps within the company and help to avoid replicated work.

Roadmaps are usually made by a small group of technology specialists from the same work group. This goes against existing roadmapping theory that states that a roadmap should ideally be constructed in a workshop setting with participants coming from many levels in the company and with different backgrounds and competencies. Tolfree and Smith, (2009), Petrick and Provance, (2005), Phaal and Palmer, (2010) and Kerr, Phaal and Probert, (2012). In other words, the literature recommends a cross-functional workshop in order to fully gain all the benefits offered by a roadmapping exercise. Moreover, it is quite common that the roadmaps tend to not be distributed and communicated outside of the particular group that made the roadmap in the first place. Communication of a roadmap to others in the organization is also hampered by the fact that the roadmaps are likely to be very technical and hard to understand to outsiders that do not possess any great knowledge of that particular field.

A few interviewees questioned the value of roadmapping. They feel that they already know everything that is written on the roadmap and that it therefore is not very worthwhile to spend time making a roadmap. This problem is connected to the problem in the previous paragraph, and it seems to stem from a lack of understanding when it comes to how roadmapping should be carried out in order to obtain all of the benefits offered by the method. Since it is mostly the same small group of specialists constructing, updating and using any given roadmap the benefit to that same group might indeed not be very great. One of the main points of conducting a roadmapping exercise is to bring people with different backgrounds together and let them create and share in a mutual understanding of the discussed topic, technologies, future development needs and identified problems. Consequently, when the same small groups of people always construct and update the same roadmap one of the main benefits of roadmapping is lost. This problem is made worse by the fact that roadmaps are often not distributed and communicated to other employees within the organization.

Another challenge, in particular at Volvo Technology, is that the roadmaps are almost entirely technology focused. There is thus not much customer or market focus in the roadmaps. To increase the customer focus of roadmaps researchers use cross-functional teams for roadmapping workshops and market layers to see how a technology fits with the future market and value layers to identify how a technology is supposed to generate value. Beeton, Phaal and Probert (2008) and Dissel's et al. (2009). Ericsson handles this problem by developing their roadmaps together with their customers and can in that way assure that the developed technology actually will create value for their customers.

A consequence of the low level of connections between the formerly separate companies that now comprise Volvo Group Global Trucks Technology (VTEC, 3P, Volvo Powertrain etc.) is that it has been somewhat of a supplier-customer relation between the companies in the past. There have of course always been some official forums and channels of communication in existence. These are relatively weak however, and most communication comes from informal contacts within the personal networks of employees. This leads according to literature to a number of opportunities for improvement. For example, a increased level of transparency and awareness of exactly what technologies are being developed and what projects are being worked on around the company; improvements of resource allocation and reducing the risk of doing the same work twice; create formal networks for ensuring that employees work cross functionally and reduce the risk that new employees will be left out of the loop and do not get access to valuable information. Increased awareness of the on-going projects within the organization and opportunities to give feedback to projects outside the own department can potentially help to increase the acceptance 3P have for technologies developed at VTEC.

But as Saffo (2007) explains (as discussed in the chapter 'Literature review' above), a forecast does not necessarily have to be accurate in order to be of value to a company. Rather, a good forecast should be "effective" and show what could potentially happen under a certain set of circumstances. The question is therefore if implementing a value based roadmapping approach at Volvo Technology can help to make these kinds of forecasts and predictions about a technology's future value more effective and useful to Volvo.

Research question 3

Finally, the last research question to answer is:

3. *How should a roadmapping process for Volvo Technology be designed in order to take advantage of the roadmapping benefits described in literature?*

The general purpose with roadmapping is according to Probert and Radner (2003) to help a company reach its goals. If roadmaps are built locally by technical experts it will not enhance comparison of technologies to other technologies that solve the same problems or can lead to other improvements in the same feature area. Portfolio management is according to Cooper, Edgett and Kleinschmidt, (2002) to maximize the value of a company's portfolio. In order for the roadmapping process to generate input to the portfolio management it is necessary to evaluate and compare different technologies, serving the same feature area, to each other. It is not the potential of a technology that is interesting; it is how high the potential of one technology is, in relation to other technologies. At Volvo Technology this would mean that a technology leading to an improvement within for example safety should be compared with other technologies serving the same feature area. This could be done in a "Feature Roadmap" showing the development needed to reach performance oriented goal within a feature area. Further the feature roadmap

Feature specialists at Volvo GTT's Product Planning function are responsible for assuring that the new products developed will be competitive and fulfil the customers' requirements within their respective feature area. However the feature specialists have mostly been focused on setting the requirements for new products. We suggest that the technology focused roadmaps should be complemented with roadmaps that show the development within specific feature areas. Feature specialists should then be responsible for the roadmap concerning their particular feature area.

The roadmapping and technology forecasting is often managed by a single or a few technological experts at VTEC, which according to Meredith & Mantel (1995) is common in many industries. However, Meredith & Mantel (1995) argues that it is very rare that a single person has the requisite level of expertise needed in all different fields involved. Instead many people with different backgrounds and functions should build roadmaps together in workshops. In line with Tolfree and Smith, (2009), Petrick and Provance, (2005), Phaal and Palmer, (2010) and Kerr, Phaal and Probert, (2012) we propose cross-functional workshop teams to be used. A complete roadmap within one feature area will be too large for one single workshop. Phaal and Palmer, (2010) recommends 15-25 participants in one workshop which mean that several different workshops will be needed in order to build or review the roadmap within one feature area. In order to not exceed the number of participants it is recommended that a workshop is focused on one technology area per workshop.

Functions that need to be represented in the roadmapping workshops depend on the technology and the feature area investigated but should at least include research, product development, marketing, which is in line with Kerr, Phaal and Probert, (2012) that suggests a diverse group of people. Further, product development has knowledge about the present products, which according to Niiniluoto, (2003) is crucial when building statements about the future.

Workshop and roadmap design

The structure of the developed roadmapping workshop is based on many sources. Two sources from the literature have however been more prominently used than the rest. These two are the paper 'Value Roadmapping' by Dissel, Phaal, Farrukh and Probert (2009) and the book 'Roadmapping Emergent Technologies' by Tolfree and Smith (2009). Besides these two sources a wide range of other papers have provided input to the design of the workshop. In addition to literary sources information and input gathered during the interviews has been used to increase the focus of the workshop in a way that is more beneficial to Volvo.

The final version of the developed roadmap architecture is shown in Figure 6 below. This is the architecture that was used during the two final roadmapping workshops. A description of the actual workshop can be found in the workshop guide in Appendix B. In the workshop guide each of the steps in the workshop are presented and the order in which to complete the workshop is described. By following this guide and using the roadmap template, it is possible to conduct a workshop and produce a value based roadmap, even without any prior knowledge of how to conduct this kind of workshop.

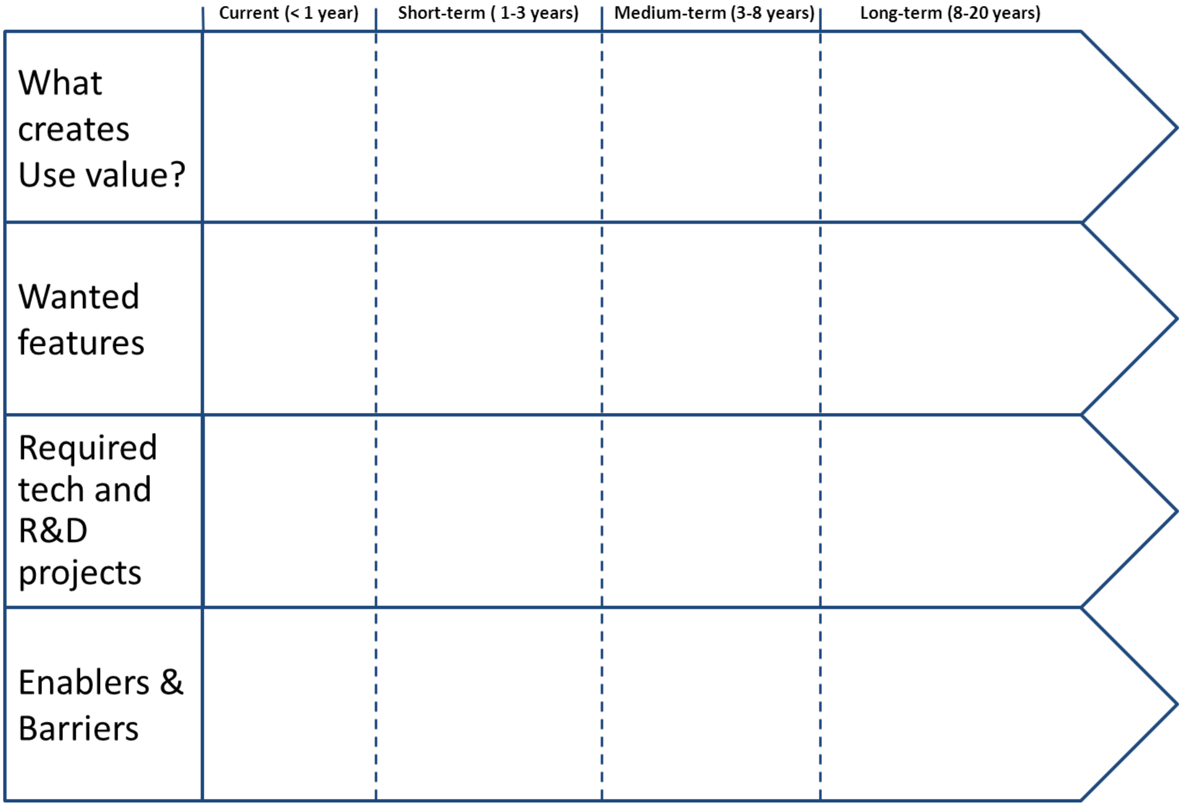

Figure 6. Final design of the roadmap architecture developed during the study

Figure 7 depicts an example of what the feature roadmap might look like conceptually once it has been completed, i.e. when all of the four layers have been filled in and the linkages between the sticky notes have been drawn up. The numbers in Figure 7 also show the order in which to complete the four different levels of the roadmap.

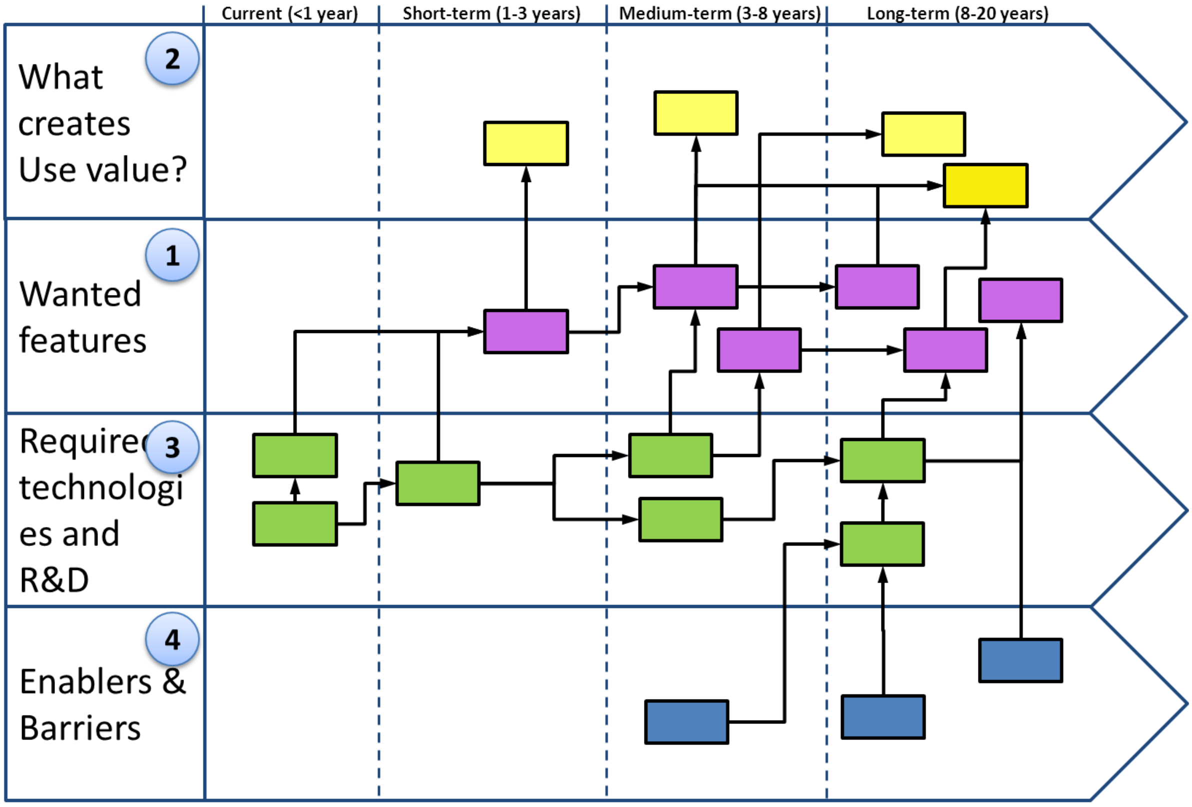

Figure 7. Example of what a completed feature roadmap might look like conceptually. The numbers to the left show in what order to complete the four layers of the roadmap.

These workshops will result in what we have chosen to call feature roadmaps. These roadmaps will be based around one technology and how it can be used and applied in a particular feature area. Volvo defines a total 34 different feature areas and in the two case workshops described in the Methodology chapter of the report we have focused on one of these feature areas and how two, one for each workshop, technologies can be applied to this particular area. The aim is to create a feature roadmap for one technology in each workshop. These many different feature roadmaps will together form a roadmap for that particular feature area, in other words, a feature area roadmap. This means that there will have to be more than one workshop carried out for the same technology; one for each feature area that the technology can be applied in.

When involving people from different departments it will become crucial to have a common roadmapping process and architecture in order to be able to focus on the actual work and not having to learn a unique process every time one is participating in a new roadmapping workshop. A workshop guide and a roadmap architecture have thus been designed and adapted to the specific needs of Volvo in mind. Previously there was no coherent framework available, which has led to different roadmaps and difficulties to compare and link roadmaps. The common roadmapping structure and architecture will enhance comparison of different roadmaps from different business units.

It is also very important to identify and appoint a suitable owner of the roadmapping process, an owner with the drive to take the roadmapping forward and not just let the process vane and die. Our suggestion is that each feature area roadmap should have a different owner and that these owners could come from the already existing Feature Coordination Teams or be the same persons that are responsible for creating Feature Development Plans at the Product Planning business unit.

The following sections will describe the proposed workshop and roadmap design. This roadmapping method is designed to deal with the identified problems and, as such, be more useful to the company than the roadmapping methods currently in use. The workshop guide that has been developed during the course of this study can be found in Appendix B at the end of the report.

Wanted features

In order to appraise the Use value of a technology it is essential to define the circumstances in which the Use value will be generated. The technology alone will not create Use value, instead the different features a technology can lead to have to be valuated. This is in line with Boer (1998) stating that technology has to be linked to other technologies and physical assets in order to reach its full potential. Bowman and Ambrosini (2000) conclude that Use value is an individual measure that, depending on the circumstances and the users' perception, will differ. This means that technology has to be considered in the context where it will be used. Hence, customer knowledge will be crucial for investigating the Use value and define the customer segment where a feature has potential to generate Use value. Wanted features are there for the base for the roadmap and the first step in the workshop.

The following steps are performed in the workshop to identify wanted features:

1) Write down features that are currently under development or investigation on sticky notes.
2) Identify new features that might be of future interest by brainstorming and describe them on sticky notes.
3) The facilitator clusters similar sticky notes together when appropriate.

What creates use value?

The 'What creates Use value?' layer in the roadmap will help to communicate how new features are thought to generate Use value for the customers, which in turn enables a discussion between the market, product development and research departments. This layer helps to increase the customer focus of the roadmap. This is something that is very important as it shifts the focus of the roadmap away from just being concerned with technology and toward a more feature and customer centric roadmap. For example, Ericsson gets a high customer focus by actually including some representatives from their customers in the workshops where the roadmaps are created. Ericsson's way of using roadmapping is thus mainly focused around communicating new features to their customers.

The "What creates use value?" layer will help to investigate the Use value that Volvo's customers will perceive when using a certain feature. The descriptions of the created Use value should be of a qualitative nature. This means that quantitative estimations and calculations of the value should be avoided unless the estimations are very reliable. Examples of where the monetary value can be determined and calculated relatively easily within Volvo are, according to interview responses, for instance technologies that save fuel.

The risk in R&D projects are extraordinarily high Boer (1998) In general, DCF calculations are not suitable for early stage technologies where the uncertainties are high (Messica, 2008). According to

Hunt et al. (2007) a qualitative description is often better than a detailed calculation when it comes to communicating and creating a common framework for the involved people. We have therefore chosen to not include any DCF calculations of technologies in the roadmapping process; instead a framework for communicating the source to the value is provided. By describing "what creates use value" a common view of how new features and technologies generate value can be spread without involving too many weak assumptions.

The following steps are performed in the workshop to identify what creates use value:

1) Divide into groups of 2-4 people. The features from the previous step should be divided equally between the groups.
2) The groups discuss the potential Use value that the features can create. Descriptions answering the question 'How will this feature generate Use value for the customer?' are then formulated on sticky notes for each feature.
3) Present, discuss and revise the sticky notes together in the full group. Then place the sticky notes in the value layer of the roadmap.
4) Linkages between the created Use value and the corresponding features are drawn.

Required Technologies and R&D projects

To be able to build a strong technology portfolio it is essential to allocate resources efficiently (Cooper, Edgett and Kleinschmidt,, 2002). This step identifies the required technologies and R&D projects needed for delivering a specific feature and helps to spread a common picture of the resources required for developing a feature.

The following steps are performed in the workshop to identify required technologies and R&D projects:

1) The same subgroups are used as in the previous step.
2) Underlying technologies needed in order for Volvo to be able to deliver the previously identified features are described on sticky notes and placed on the roadmap's technology layer.
3) Make connections to the appropriate features in the previous step.
4) Discuss and revise the technologies and projects together in the full group. Possible topics for discussion include:
    a) How much of the development should we carry out in-house?
    b) What parts of the development can we outsource?
    c) How can we protect the Intellectual Property resulting from these technologies?

Enablers and barriers

Enablers and barriers are identified last in the roadmap and are done in order to communicate the risks and crucial factors involved in developing a certain feature. Both technological and market related factors are considered with the purpose of building a common picture of how likely it is that the feature will be successfully commercialized. The risks are not quantified, instead the source of the risk are described qualitatively by identifying enablers and barriers. This layer can include for example different market needs and trends that are of importance for a feature, legal requirements and new technology platforms that enable the development of certain features. By including crucial market factors in this layer it is possible to exclude a dedicated market layer. A market layer often tends to be very general and hard to connect to the technologies in the roadmap, according to the performed pre-tests and interview findings.

The following steps are performed in the workshop to identify enablers and barriers:

1) Both technical and non-technical barriers and enablers to the technologies and features should be identified in a short brainstorming session with the whole group. The resulting sticky notes are placed on the fourth level of the roadmap.
    a) Barriers and enablers can for example be complementary technologies, alternative technologies, a lack of required infrastructure etc.
2) Make connections to the appropriate technologies in the previous step.

Rate and prioritize the identified features

In the previous steps all workshop participants have gained insight in how the different features create use value, what resources that are needed in order to deliver the different features and the risks involved in developing and commercializing the different features. Based on the information each participant makes a collected assessment and votes on the features that the participant believes have highest potential to be commercialized successfully.

The following steps are performed in the workshop to rate and prioritize the identified features:

1) In order to prioritize between the proposed features a silent voting method is used. Each participant is given 10 points to distribute among the features as he or she wish. The points are thus used by the participants to vote on the features that the participant thinks will be the most important to focus on in the future. The participants are free to choose how many points they wish to give to any particular feature; all points could for example be given to a single feature if the participant believes this feature to be especially important.
2) The participants write down the features they wish to vote for and how many points out of a total of ten that they wish to give to those features on a sticky note. The note is then given to the facilitator.
3) The facilitator counts the total number of points on each sticky note and presents the result of the voting to the group. The total number of points that is given to a feature is also written on the feature's sticky note on the roadmap.
4) The result and the question 'Are we doing something now that we should put more effort into or drop entirely?' are discussed.

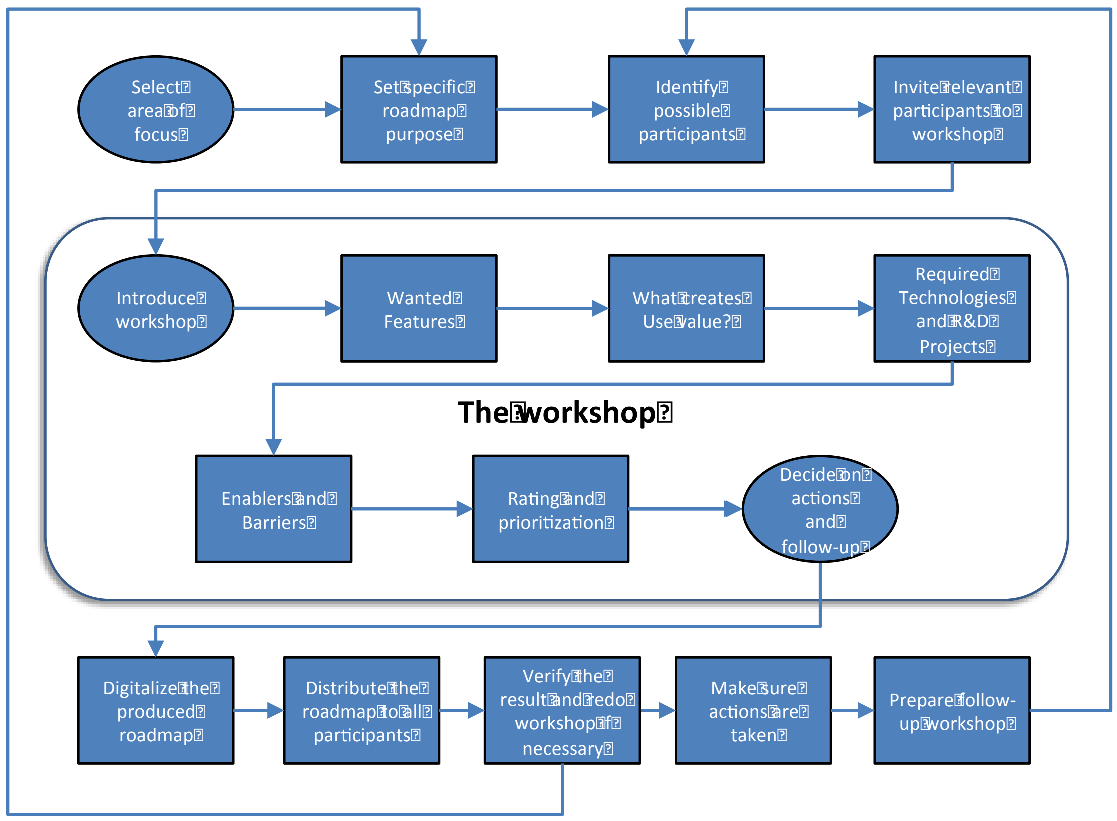

Figure 8. Flowchart depicting the roadmapping process developed during the study. Ovals represent start and end activities.

Figure 8 shows the roadmapping process in its entirety in the form of a flowchart. As can be seen in the figure, the two boxed in rows corresponds to the developed roadmap architecture shown in Figure 6 above. The first and last rows in Figure 8 represent activities that are to be carried out prior to and after the workshop respectively. The reader is referred to the workshop guide in Appendix B for a more in-depth and detailed description of each step of the actual workshop. Figure 8 also illustrates the continuous and iterative nature of the roadmapping process by the connection between the last step in the fourth row and the third step in the first row.

The purpose doing an exercise such as this is in other words to actively and exhaustively explore and investigate a new technology or feature and how it fits in with within the organization as a whole. Bringing together a group a people from many different positions in the company ensures that the investigation is exhaustive and that many different viewpoints of the issues are taken into consideration. The roadmapping method is meant to act as a complement to already established methods, product development plans for example. One of the new roadmapping method's chief advantages over the various methods currently in use is that it allows for a better overview of the feature area and the role the new technology can play within this area. It also allows for new uses of the technology to be identified and explored.

It is very important that the preparations prior to the workshop are carried out. Setting clear and realistic goals that are easy to understand for the roadmapping workshop is essential to the final result at the end of the process. Choosing the right people to participate in the workshop is also crucial. Participants should come from a range of different positions within the company in order to get many different perspectives and to take as many possible problems and opportunities into consideration as possible. Furthermore, it is also important to only invite people with roles relevant to the technology or feature area in question. The recommended number of participants to each workshop is 10 to 15 persons. This ensures that you get the necessary breadth of knowledge yet at the same time keeps the number of participants at a manageable level.

Discussion

This chapter will provide a discussion regarding the empirical findings and the results of the study. First, the differences between Volvo Technology and the two other investigated companies will be given. This will be followed by a discussion about the roadmapping workshops that have been conducted at Volvo.

Differences between Volvo and Ericsson

The two companies have different ideas and definitions of what constitutes a roadmap. A standard roadmap at Volvo is a very technical development plan for a specific feature or product, while a roadmap at Ericsson is a non-technical plan for how a product or product line will be supported, upgraded and developed in the future.

The fact that Ericsson is much more open with their roadmaps and shares them with customers is also a major difference compared to Volvo. All of Volvo's roadmaps are kept secret within the company and there is not as much of a need for Volvo to have as close cooperation with the customers as Ericsson since Volvo's customers are not as big and powerful as most of Ericsson's customers. Volvo is also not expected to upgrade a sold truck in the manner that Ericsson is expected to upgrade a, for example, base station for many years into the future. The culture and traditions in the two respective industries are very different in this regard. In the truck industry all companies more or less keep their development plans secret until they present the next truck and its new features at a tradeshow in order to impress the audience.

The two companies also have very different time and planning horizons. At Ericsson 18 months is considered long-term, at Volvo 18 months is short-term and roadmaps commonly extend several years into the future. A roadmap with a 20 year long time horizon is not uncommon at the product level at Volvo. At Ericsson however, a roadmap with this kind of time horizon is never made, at least not to the authors' knowledge. The longest strategic plans at Ericsson, that we are aware of, stretch 5 years into the future.

Ericsson Research has traditionally had a quite different relationship with the rest of the organization compared to Volvo Technology. VTEC has until recently been an altogether separate company and has because of this been a little isolated from the rest of the organization. Ericsson Research is a function directly below the head office and has thus been more tightly integrated into the wider organization. Their ways of working has also been a bit different. ER is more tightly controlled than VTEC, but it is still allowed to take on an exploratory role when it comes to much of its activities. Volvo Technology has more or less been allowed to do its own thing, with relatively little input from the other companies within the Volvo Group. This has sometimes resulted in what was described by an interviewee as a sort of "customer-supplier relationship" between VTEC and the rest of the organization.

Differences between Volvo and Tetra Pak

A major difference between Volvo and Tetra Pak is that Tetra Pak uses a structured approach to roadmapping and a tool that is ubiquitous in the whole organization. Tetra Pak have shorter time horizons compared to Volvo and utilizes larger, as well as cross-functional, teams in their roadmapping workshops. Large cross-functional teams is in accordance with the recommendations of the literature and means that Tetra Pak will be able to capture more of the benefits offered by a roadmapping exercise compared to Volvo, who does not utilize large cross-functional workshop teams.

Tetra Pak also do Discounted Cash Flow calculations in the early stages of technology development. This is often very hard to do because of the inherent uncertain estimations that have to be made. Projects also commonly run the risk of being cancelled prematurely, or not even being started at all, as is discussed in more detail in the literature review.

The roadmap workshops

From the tests of the roadmapping method that have been performed it can be concluded that the method’s main strength is its ability to bring together people from different parts of a company who normally have very little contact with each other. The participants gain a common view and understanding of the subject area that the workshop deals with. They can then bring this understanding back to their own departments and can use this new knowledge, together with the produced roadmap, to further spread the same understanding within their own departments and working groups. This is something that is lacking with the current roadmap processes at Volvo. Another very important use of this roadmap and workshop method is of course that it gives rise to many new ideas for how a technology can be applied as well as suggestions for new developments within the field in question.

This means that the developed roadmap method is very useful in situation where there is a need for increased collaboration and communication between different business units within a corporation and when you want to identify new applications for technologies. It is also very useful when you want to create a better overview of what projects are running and what development is being carried out around an organisation. This leads to reduced costs due to a higher degree of efficiency when it comes to allocating resources and avoiding doing the same work more than once in a few different departments of a company.

Overall, the participants were happy with the results and the outcome of both the wireless sensor workshop as well as the augmented reality workshop. Some issues were however brought up and two main problems are identified from the wireless sensor workshop. The first problem with this workshop was that the maintainability and up-time focus that had been decided on in advance was lost during the workshop. Instead, most of the participants’ ideas ended up being broad and general and thus lacking a particular focus on maintainability. The main reason that this happened is that we as facilitators should have put more effort into stressing the importance of keeping the focus that had been decided on. Another reason may be that many of the participants were not fully prepared for the workshop and because of this they probably strayed easier from the maintainability subject. As mentioned, losing the maintainability and up-time focus resulted in a roadmap that is broader and more general to the area of wireless sensors. A broader roadmap is in itself not necessarily a bad thing however, just not the intended result for this particular workshop exercise and roadmapping method.

The second problem identified with the wireless sensor workshop was the shortage of time. As mentioned above, in addition to the workshop itself being shorter than we would have wished, some of the steps also took longer to complete than anticipated. In the end this lack of time lead to only the two first of the four layers of the roadmap being completed. Despite this, the most important parts of the roadmap were still completed, i.e. the new features and their associated creation of Use value for customers and the ranking of the features, but the roadmap is of course not as fleshed out and detailed as it would have been with more time.

A reason for the workshop running late is that the 'Wanted features' step took a very long time to complete relative to the total time available. This step might have been at least somewhat faster if the participants had read their own notes aloud to the rest of the group themselves when they posted them on the roadmap instead of one of the facilitators reading all the notes at the same time once they had all been placed on the roadmap. Most of the notes had to be explained in more detail by their respective authors and it took a long time to go through and have a discussing about them all. It would thus help make the workshop be less time-consuming and run more smoothly if each participant is responsible for communicating their own sticky notes to the rest of the group when they post a new note on the roadmap architecture. Doing this might also reduce the cluttering on the roadmap and make clustering similar notes easier since they could be clustered from the beginning, without a separate discussion about whether or not they should be clustered with a particular note or if it is better to cluster it with some other note.

These two problems were kept in mind for the augmented reality workshop and we succeeded to deal with both of them to some extent. For the augmented reality workshop we were able to retain the maintainability focus throughout the course of the workshop to a much higher degree compared the wireless sensor workshop. This meant that discussions were more focused, to the point and much more relevant to the chosen topic compared to the discussions of previously performed sensor workshop. This was achieved because we as facilitators emphasized the importance of sticking to the topic much more and reminded the participants of this when they strayed off topic.

When it comes to the length of the workshop the problem was only partially solved for the augmented reality workshop however. Even with the longer timeframe compared to the wireless sensor workshop, there was still not enough time to finish all of steps of the workshop and produce a complete roadmap. Only one roadmap layer was left unfinished in this workshop however, compared to two for the previous workshop. From this it can be concluded that a suitable length of time for the workshop probably is around three hours. This will give the participants enough time to complete all of steps and discuss the results while at the same time not be so long as to make people lose interest, or not agree to participate in the first place. Almost all of the surveyed participants agree that the workshop would have benefitted from more time. Facilitators more experienced in running these kinds of workshops can make them run more smoothly and maybe finish the workshop in 2,5 hours instead of 3. Three hours is however recommended as this will allow for a more detailed roadmap as well as deeper and more meaningful discussions on the subject.

Participants reported having some difficulty when completing the 'Required technology and R&D projects' layer of the roadmap. This difficulty is attributed to the fact that future features have a very high degree of uncertainty about them and that it because of this uncertainty is difficult to estimate what underlying projects and technologies are needed in order to create these features. This challenge is however something that needs to be faced sooner or later is hard to circumvent with the current design of the roadmap.

For both of the workshops, the participants came from four different business units within the Volvo Group and they have different areas of responsibility and expertise. This makes this roadmapping process different from the usual roadmapping work that is ordinarily carried out at Volvo. Even more cross-functionality among the participants would be positive for the output of the workshops however. Thus attempting to create an even higher degree of cross-functionality in future workshops by including additional business units and competencies is encouraged. To do this, more participants need to be invited. Eight attendees were a good number for this first round of workshops because it made the workshops more manageable. In the future however it is recommended to have between 10 and 15 participants for each of the workshops. This will make the size of the workshop manageable and yet still provide a good range of different competencies and cross-functionality among the workshop participants. Furthermore, it is important to not only invite people with technical competences but also invite people from marketing, sales and after-market functions.

One thing that was noticed during the creation of the wireless sensor roadmap was that no participant posted a sticky note in the 'Long term' column. This might be because the time scope was set to far into the future. The long term was set to mean between 10 and all the way up to 25 years into the future. Medium term was 5 to 10 years, short term was 1 to 5 years while 'Current' meant projects that will be finished in under one year's time. Some participants felt that it was hard to come up with ideas for the long term because of the uncertainty regarding the course of the future development at a point so far ahead in time.

The time horizons were shortened for the augmented reality workshop in order to see if it would yield a different result and a more even spread of sticky notes in all of the columns of the roadmap. The time limits that were used during the augmented reality workshop are less than 1 year for current projects, 1-3 years for the short term, 3-8 years for the medium term and 8-20 years for the long term. Some features were indeed posted in the 'Long term' for this workshop but it is unclear if this is because of the shorter time horizons, if it has more to do with the topic of Augmented Reality itself, or if it is a mix of both these reasons.

Another thing that was noticed during both of these two workshops is that the notes written by the participants tended to be quite general in their nature, especially notes describing what use value will be created by a feature. This means that the facilitators need to step in and ask participants to clarify their notes and make them more detailed. For example, a note that only says that value is created by making something "More effective" is not a good way to describe the value that that feature create. What is needed In this case is to break down in what ways a particular feature can help make something more effective.

Some problems arose after the workshops when the produced roadmaps where to be saved and digitalized. The roadmaps produced during this thesis were translated from the physical copy into PowerPoint format and saved. Since PowerPoint is not designed with this in mind the resulting roadmaps cannot be presented as well as in specialised roadmap software. It was difficult to fit all of the information on the roadmap into a single PowerPoint slide and it would probably be nigh on impossible to translate larger and more detailed roadmaps into this format. It is thus recommended that Volvo evaluates and introduces a commercial roadmapping software in order to make the digitalization of more complex roadmaps easier. This will also serve to make the digital roadmaps themselves more useful as it would be easier to get a good overview of the content and how everything fits together within the context of the organisation.

A concern with restricting the roadmaps to a particular feature area, instead of letting workshop participants think freely of applications for the technology in question in all feature areas, is that there is a risk of missing potential radical new innovations that does not fit within the specified feature area for the workshop. In these situations it is important that the facilitators do not stifle the participants' creativity and allow them to further discuss such idea. When such discussion are concluded however the facilitator needs to steer the workshop back to the specified feature area in order to not lose focus of the topic at hand. The ideas that do not fit in on the feature roadmap should be put aside and be dealt with in another more, appropriate workshop.

Conclusion

This chapter will provide answers to the three research questions that were proposed in the beginning of the report as well as a concluding discussion regarding the roadmapping method that has been developed during the course of the thesis. Furthermore, suggestions of potential additional future research will be presented at the end of the chapter.

The roadmapping method

By applying the roadmapping method that has been developed during the course of this thesis Volvo would be able to increase the number of benefits that its roadmapping process creates for the company. In conclusion it can be said that the participants of a workshop will gain a common view and understanding of the subject area that the workshop deals with. They can then bring this understanding back to their own departments and can use this new knowledge, together with the produced roadmap, to further spread the same understanding within their own departments and working groups. This is something that is lacking with the roadmap processes in use today at Volvo. Another important benefit of this roadmapping method is that it gives rise to many new ideas for how a technology can be applied as well as suggestions for new developments within the field in question.

This means that the developed roadmap method is very useful in situations where there is a need for increased collaboration and communication between different business units within a corporation and when you want to identify potential new applications for technologies and review the usefulness of these technologies as well as their potential to create value for the customer. It is also very useful when you want to create a better overview of what projects are running and what development is being carried out in an organisation. This leads to reduced costs due to a higher degree of efficiency when it comes to allocating resources and avoiding doing the same work more than once in different departments of the same company.

Research question 1

1. *How is roadmapping carried out at Volvo Technology today?*

The roadmapping is managed in an ad-hoc manner by the person, or persons, who are responsible for developing a particular roadmap. These persons are most often technical specialists and the roadmaps tend to be created by this specialist him or herself or by a small team of specialists from the same work group. This leads to roadmaps that tend to be very technical in their nature and with a low level of customer focus.

Research question 2

2. *What are the main differences between how roadmapping should be managed according to literature and Volvo Technology's way of working with roadmapping?*

A number of problems have been identified with Volvo Technology's current roadmapping processes and it can be concluded that Volvo does not currently enjoy all the benefits that roadmapping can offer a company. The main problems that have been identified during the study are a lack of a companywide structure and roadmapping framework, locally managed roadmaps created by a only single or a few technical specialists without much, if any, input from other parts of the organisation that lead to very technology focused roadmaps lacking a customer focus, and problems with cross-departmental communication and creating overviews of what projects are on-going and what is being developed in different business units within the company.

Research question 3

3. *How should a roadmapping process for Volvo Technology be designed in order to take advantage of the roadmapping benefits described in literature?*

There are many potential ways in which to improve the existing roadmapping processes in use at Volvo technology today. We believe that implementing the method proposed in this Master's thesis will help solve many of the problems identified with the current processes. One change from the current way of working is that roadmaps will be created by cross-functional teams in a workshop setting, not created by technical specialists working on their own. Another change is that a companywide structure common to the whole organisation for roadmapping will be introduced. A third change is the ownership structure of the roadmaps. Technical roadmaps will still be owned by technical specialists but the new feature area roadmaps, and the underlying feature roadmaps that each feature area roadmap is comprised of, and will instead be owned by the Product Planning department.

Future research

To fully evaluate the proposed roadmapping method more tests and workshops need to be performed. One thing that should be carried out is to create more feature roadmaps in a feature area and build a greater feature area roadmap out of these feature roadmaps and evaluate the results of this. The method should also be tried in other organisational settings at other companies. The method should also be evaluated in comparison to other existing methods that serve a similar purpose. In addition, a new software tool for capturing, storing and updating roadmaps need to be investigated and introduced in the company.

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Appendix

List of appendices:

- Appendix A – Interview questions
- Appendix B – Workshop guide
- Appendix C – Pre-test roadmap architecture
- Appendix D – Interview findings

Appendix A – Interview questions

The interview questions used during the thesis are presented below. The questions are in Swedish since all of the interviews were conducted in Swedish.

Interview questions - Volvo

1. Vilken är din roll?
2. Har du några arbetsuppgifter som berör utvärdering av nya teknologier?
3. Beskriv de olika stegen för att utvärdera en ny teknologi.
4. Vilket tidsperspektiv har ni när ni utvärderar teknologier?
5. Vilken TRL är teknologierna i när de utvärderas?
6. Vem beslutar vilka teknologier man ska investeras i?
7. Vem är ansvarig för portföljen med olika teknologier?

8. Hur avgör ni om en teknologi är värdefull för Volvo?
9. Vad är det som gör en teknologi värdefull?
10. Hur säkerställer ni att ni utvecklar teknologier som kommer vara värdefulla för era kunder?
11. Har ni några sätt för att bedömma värdet på nya teknologier?
12. Om ni väger mellan att utveckla två teknologier, hur avgör ni då vilken som har störst potential?
13. Hur hanteras teknologier som inte hamnar inom något key technology area?
14. Hur stor del utvecklingsprojekten leder till något som kommersialiseras?
15. Hur skulle du göra för att avgöra om en teknologi är värdefull för era kunder?

16. Beskriv roadmappingprocessen.
17. Hur ofta hålls roadmappingworkshops?
18. På hur stor andel av de utvärderade teknologierna görs en roadmapp?
19. Vad avgör om ni ska göra en roadmap för en teknologi?
20. Hur lång tid brukar det ta att göra en roadmapp?
21. Vilka personer brukar delta i roadmappingworkshopparna? Antal?
22. Vem är ansvarig för att initiera en roadmapprocess?
23. Hur dokumenteras roadmappen? Vem har ansvaret?
24. Uppdateras roadmappen?
25. Tycker du att något saknas i dagens roadmapprocess?

26. Finns det några svårigheter med att göra en roadmap?
27. Hur väl brukar roadmapparna stämma med verkligheten?
28. Är det lätt att veta hur man ska göra i workshoppen

29. Hur sätts fokus för en roadmap?
30. Hur används resultatet från en roadmap?
31. Vilken nytta ser du med roadmappingen?

32. Hur fortsätter utvärderingen av teknologin efter att roadmappen är gjord?
33. Hur tar organisationen i allmänhet emot nya arbetsmetoder?
34. Vilka andra personer bör vi prata med?

Interview questions – Ericsson

1. Vilken är din roll?
2. Har ni någon strukturerad metod för att bedömma värdet på nya teknologier/funktioner?
3. Hur avgör ni om en teknologi är värdefull för Ericsson?
4. Vilken möjlighet har ni att påverka strategin för den långsiktiga teknikutvecklingen?
5. Hur gör ni för att styra den långsiktiga utvecklingen av nya produkter?
6. Är ni medvetna om vilka project som drivs på researchavdelningen?
7. Har ni överblick över vilka produktutvecklingsprojekt som drivs inom ert område?
8. Hur tas nya funktioner, som är utvecklade av researchavdelningen, emot av organisationen?
9. Hur går ni tillväga för att utvärdera en ny teknologi eller funktion?
10. Hur tidigt försöker ni beräkna värdet av nya teknologier eller funktioner?

11. Hur gör ni när ni tar fram en roadmap?
    a. Hur ofta hålls roadmappingworkshops?
    b. Hur lång tid brukar det ta att göra en roadmapp?
    c. Vilkapersoner/kompetencer brukar delta i roadmappingworkshopparna? Antal?
    d. Vem är ansvarig för att initiera en roadmapprocess?
    e. Hur dokumenteras roadmappen? Vem har ansvaret?
    f. Använder ni er av något roadmappingverktyg?

12. Är roadmapparna länkade? Hur?
13. Tycker du att något saknas i dagens roadmapprocess?
14. Finns det några svårigheter med att göra en roadmap?
15. Hur väl brukar roadmapparna stämma med verkligheten?
16. Är det lätt att veta hur man ska göra i workshoppen
17. Hur används resultatet från en roadmap?
18. Vilken nytta ser du med roadmappingen?

Workshop evaluation questions

1. Har du haft kontakt med de andra deltagarna tidigare?
    a. Hur många?
    b. Hur ofta?
2. Tyckte du att de personer som deltog var de rätta för uppgiften? Fattades det någon relevant kompetens eller en viktig representant från någon annan avdelning?
3. Tyckte du att workshopens fokus var relevant?
4. Hur var workshopens tidsaspekt?
    a. För lång/kort?
    b. Var det tillräckigt med tid för att diskutera allt?
    c. Las det för mycket/lite tid på någon aspekt?
5. Var du medveten om vilken utvekcling som pågick på de andra avdelningarna innan?
    a. Lärde du dig något som du inte redan visste om vilka features som är under utveckling?
6. Märkte du att du kunde dela med dig av saker (projekt som drivs eller nya features som är på gång till exempel) som de andra deltagarna inte kände till i förväg?
7. Tror du att du kommer att ha nytta av resultatet av workshopen i framtiden?

Appendix B – Workshop guide

General guidelines:

a) Write only one idea/technology/feature/point/etc. on each sticky note
b) Use sticky notes in different colors for each layer of the roadmap
c) The person who posts a sticky note on the roadmap is responsible to briefly communicate and explain the message on the note to the rest of the group

1) Introduction and background

a) All participants introduce themselves to the group by giving a brief summary of their background, where they work and what they do.
b) The facilitators go through why the workshop is being conducted and what the purpose and aims are.

2) Wanted features

a) Write down features that are currently under development or investigation on sticky notes.
b) Identify new features that might be of future interest by brainstorming and describe them on sticky notes.
c) The facilitator clusters similar sticky notes together when appropriate.

3) What creates Use value?

a) Divide into groups of 2-4 people. The features from the previous step should be divided equally between the groups.
b) The groups discuss the potential Use value that the features can create for the cusomers. Descriptions answering the question 'How will this feature generate Use value for the customer?' are then formulated on sticky notes for each feature.
c) Present, discuss and revise the sticky notes together in the full group. Then place the sticky notes in the value layer of the roadmap.
d) Linkages between the created Use value and the corresponding features are drawn.

4) Required Technologies and R&D projects

a) The same subgroups are used as in the previous step.
b) Underlying technologies needed in order for Volvo to be able to deliver the previously identified features are described on sticky notes and placed on the roadmap's technology layer.
c) Make connections to the appropriate features in the previous step.
d) Discuss and revise the technologies and projects together in the full group. Possible topics for discussion include:
   i) How much of the development should we carry out in-house?
   ii) How can we protect the Intellectual Property resulting from these technologies?

5) Enablers and Barriers

a) Both technical and non-technical barriers and enablers to the technologies and features should be identified in a short brainstorming session with the whole group. The resulting sticky notes are placed on the fourth level of the roadmap.
   i) Barriers and enablers can for example be complementary technologies, alternative technologies, a lack of required infrastructure etc.
b) Make connections to the appropriate technologies in the previous step.

6) Rate and prioritize the identified technologies and features

a) In order to prioritize between the proposed features a silent voting method is used. Each participant is given 10 points to distribute among the features as he or she wish. The points are thus used by the participants to vote on the features that the participant thinks will be the most important to focus on in the future. The participants are free to choose how many points they wish to give to any particular feature; all points could for example be given to a single feature if the participant believes this feature to be especially important.
b) The participants write down the features they wish to vote for and how many points out of a total of ten that they wish to give to those features on a sticky note. The note is then given to the facilitator.
c) The facilitator counts the total number of points on each sticky note and presents the result of the voting to the group. The total number of points that is given to a feature is also written on the feature's sticky note on the roadmap.
d) The result and the question 'Are we doing something now that we should put more effort into or drop entirely?' are discussed.

7) Decide on actions and agree on a way forward

a) Discuss appropriate way to move forward after the workshop has concluded.
b) Select responsible persons for the tasks that shall be performed.
c) Decide on a new meeting for reviewing the roadmap.

Appendix C – Pre-test roadmap architecture

	Past	Short-term	Medium-term	Long-term
Market trends and drivers				
Added customer value				
Wanted features				
Required technologies and R&D				
Enablers & Barriers				