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Defining Technological Innovation Deployment Through Market Research: University Spinoff Case

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Author: Mika Mauno
Supervisor: D.Sc. Emil Kurvinen
Examiners: Prof. Timo Kärri
Prof. Jussi Sopanen

ABSTRACT

Author: Mika Mauno	
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This study aims to create and apply a market research -based methodology for supporting the planning of a technology commercialization process in the context of a high-tech innovation created in a university environment. As these types of innovations can be generally used in a variety of contexts, there is a need for methods that can be used to define viable and profitable paths for deploying these innovations into the industrial environment.

The study reviews information available in scientific publications concerning the issues associated with innovation deployment and university spinoff creation as well as theoretical tools for overcoming such issues in early-stage market research and product planning. Based on findings from this research, a combined framework is suggested, where the basic ideas of Quality Function Deployment are supplemented with other commonly used methods to structure and analyze information from market research in order to support decision making in innovation deployment planning.

The suggested methods are applied in a case context, where they are used to obtain and analyze mainly qualitative information for the purposes of a potential university spinoff project. A significant amount of valuable information is obtained, but practical constraints limit the full application of the framework. Further research for improving the framework is suggested.

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Tutkimuksen tavoitteena on luoda ja hyödyntää markkinatutkimukseen pohjautuvaa metodologiaa teknologian kaupallistamisprosessin suunnittelun tukemisessa yliopistoympäristössä kehitetyn high-tech innovaation kontekstissa. Koska tämän tyyppiset innovaatiot ovat yleisesti hyödynnettävissä useissa eri konteksteissa, tarvitaan menetelmiä, joilla voidaan määrittää mahdolliset ja tuottavat polut näiden innovaatioiden jalkauttamiseen teolliseen ympäristöön.

Tutkimus luo katsauksen tieteellisistä julkaisuista saatavaan informaatioon liittyen innovaation jalkauttamisen ja yliopisto-spinoffien perustamisen ongelmiin sekä näiden ongelmien ratkaisemiseen soveltuviin työkaluihin varhaisen vaiheen markkinatutkimuksessa ja tuotesuunnittelussa. Tutkimuksen löytöjen perusteella ehdotetaan yhdistettyä viitekehystä, jossa Quality Function Deployment -metodologian perusteita täydennetään muilla yleisesti käytetyillä menetelmillä markkinatutkimuksesta saatavan informaation strukturoimiseen ja analysointiin innovaation jalkauttamiseen liittyvän päätöksenteon tarpeita varten. Ehdotettuja menetelmiä sovelletaan case-kontekstissa, jossa niitä käytetään pääasiassa kvantitatiivisen informaation keräämiseen ja analysointiin potentiaalisen yliopisto-spinoff projektin tueksi. Merkittäviä tuloksia saavutetaan, mutta käytännön rajoitteet estävät viitekehyksen täyden hyödyntämisen. Jatkotutkimusta kehyksen kehittämiseksi ehdotetaan.

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ACRONYMS

AHP	Analytic Hierarchy Process
AMB	Active Magnetic Bearings
B2B	Business-to-Business
HoQ	House of Quality
IoT/IIoT	(Industrial) Internet of Things
IP	Intellectual Property
IPR	Intellectual Property Rights
IT	Information Technology
PoC	Proof of Concept
QFD	Quality Function Deployment
R&D	Research and Development
SQD/SQFD	Software Quality (Function) Deployment
VOC	Voice of the Customer
VOCT	Voice of the Customer Table

1 INTRODUCTION

Introducing a new technological innovation is never a simple task. Even if an idea has obvious advantages, getting it adopted requires significant time and effort as there are always barriers to change that need to be overcome. To accomplish this in a financially sustainable manner, one must combine technical expertise with an expert understanding of market needs and behavior. However, there is usually a disconnect between these types of expertise. Language, focus and priorities can be very different between a commercial context and a technical research context. Translating the weak signals obtained from market research into desired technical qualities can be a tough challenge. As such, a methodical approach is needed to bridge this knowledge gap and to help define a financially viable innovation deployment process.

One often studied method for deploying market signals into product development is Quality Function Deployment (QFD), but this has mostly been practiced in the context of physical product development by established industrial actors and most often in incremental development. Radical innovations and service and software products can be noted to require some different development methods compared to physical products, but the core idea of translating market signals into technical requirements can still be applied. Universities have been recognized as an important source of innovations, but many discoveries never reach markets as they are not defined enough to be adopted by industrial actors. As such, there is need for a methodology that would enable market-driven radically innovative product development, specifically in the context of university innovations.

A practical example of this need arose in the LUT University, where a new technological solution had been found highly useful in many contexts, but researchers had difficulty defining a development path towards creating a commercially viable product. To solve this issue, this study set out to form and apply a methodology for assisting in defining a technological innovation deployment path through a customer-involved analysis of market needs.

1.1 Background of the study

This study was conducted for the purposes of a TUTL-project (Tutkimuksesta Liiketoimintaa, “business out of research”) in the LUT School of Energy Systems, which started in the autumn of 2018. The aim of the project is to study the potential of commercialization of a modeling and analyzing technology, which has been developed in the LUT University. The technology was gradually formulated by the Machine Dynamics research team and leading professor Jussi Sopanen for their own research, teaching and machine design purposes. Owing to financial incentives provided by Business Finland after successful negotiations in early 2018, a project team was finally formed to further develop and customize the technology used in research e.g. into a commercial software product, which could be widely used in multiple industries.

Before this study began, the technology mainly existed as a general concept, which was applied through program code in licensed simulation software. No presentable tool had yet been developed. Comments from industrial experts had validated a need for the technology, as it could likely enable the easier identification of the key sources of increases of vibrations in rotating machines; these vibrations have been noted as a major cause of machine failures, yet performing the analyses necessary to understand and prevent vibrations is very difficult with existing solutions. However, much further development is required before the solution can be applied in the industrial environment. The project team had realized that in order to be able to create a commercially attractive product with their limited time and resources, they needed more information about actual customer needs and potential market segment characteristics to determine the early product development and commercialization paths. The ultimate goal at this stage is to prepare the team to launch a university spinoff venture, if the technology can be determined to be valuable enough to sustain a business.

This study was commissioned to find and document industrial needs relating to the potential applications of the technology and discover the most valuable opportunities for commercialization. This data would then be used in deciding which product feature developments should be prioritized in time and resource allocation to achieve maximal market penetration and profitability in the short term with given restrictions. Ideally, the results would also guide future study and developments in further scaling the business.

1.2 Study objectives and delimitations

The objective of this study is to produce an analysis of customer needs and market potential, which can be used to guide the early stages of product development and customer interactions. To achieve this, theories formed in earlier studies must be synthesized and adapted to create a framework that can support the rather unordinary deployment process of a technological innovation that is based on university research. This also requires studying the findings of previous research concerning the formation of university spinoffs. The goal is to create a practical format for presenting data obtained from market research that allows these results to be combined with technical knowledge. The result should create valuable information for decision-making during product development, networking and marketing.

The main questions are:

- How can a university-based team decide the first product deployment path for their innovation, when market signals are weak?
- What factors should be considered when presenting a new technology to potential customers?
- How can the market potential for different solutions be assessed for a research-based concept that does not yet exist as a product?

Due to the status of the case project, the empirical part of the study is mainly delimited to the earliest stages of innovation deployment, leading up to the creation of the first prototype software product. While the results should ideally support the founding of a spinoff company in the future, no direct suggestions for the organization or business model of said company will be given. As such, the estimation of profitability in different market segments will be kept at a relative level, rather than directly estimating cash flows. Legal issues such as property rights will also be mostly left out of the discussion, as despite their overall importance in innovation deployment, they are not directly linked to the product development processes, which are the focus of this study.

1.3 Research methodology and information sources

The theoretical part of the research presented in section 2 is conducted as a literature review, where scientific books and internationally published articles available at the Lappeenranta Academic Library and LUT Finna databases are studied. The initial research approach was to find information related to the creation of university spinoffs as well as applicable methods of market research in this context. Additional theoretical tools were then selected for structuring market research information, and the information requirements of these tools were used to further define the market research process. Critical evaluation of the credibility of models and suggestions presented in this report has been conducted on the basis of wideness of supporting data and usage in related research. The new framework presented in section 2.4 is based on a synthesis of the studied theories. Initial evaluations are logical deductions based on early experiences with the utilization of the framework.

Section 3 describes a case study, which aimed to fulfill the information needs of the commissioning project team as described earlier. Section 3.1 presents the initial state of the case project based on discussions and existing internal documentation, as well as logical observational deductions. Some references are also made to other studies to provide more context for the technologies related to the case project. Section 3.2 summarizes the progression and extent of utilizing the framework presented in section 2.4 in the described case and presents obtained results. The underlying data is mainly qualitative information obtained through interviews, though some limited quantitative evaluations were also obtained through surveys and utilized. The conclusions and implications presented in section 4 are based on the evaluation of the research results conducted with the co-operation of the project group.

1.4 Structure of the study

This study begins with a look at some methods and tools of market research defined in earlier studies, which are deemed applicable to the case project to some extent. In the next part, the context of the study is defined through a literature review concerning university spinoffs. Utilizing these parts, a combined framework for supporting the planning of the deployment of a new technological innovation, specifically through a university spinoff, is suggested. The initial state of the case project (BRAIN) is then presented for additional context, followed by a study where the suggested framework is applied for said project. Adjustments to the theoretical framework will be made as deemed necessary based on practical observations. Finally, conclusions are presented, where the applicability of the framework is discussed and suggestions are made for further studies as well as for the future development of the potential BRAIN spinoff.

2 THEORETICAL METHODS

In order to solve the research issues, the theoretical contexts and tools of market research and university innovations should first be defined. The following subsections contain a literature review of relevant topics and methodologies, culminating in the creation of a new combined framework intended for the purpose of providing the necessary information for planning university innovation deployment.

2.1 Methods of market analysis for innovations

In the context of new technological innovations, determining which market research methods should be used and how their results should be interpreted requires the consideration of the unique aspects of innovation adoption. One notable factor when developing new market offerings is the differences between *reactive* and *proactive* market research techniques. Commonly used reactive techniques include surveys, in-depth interviews and focus groups. These techniques concentrate on capturing customer's previous experiences, with the participants responding to stimuli from the researcher. This allows the discovery, understanding and satisfaction of customers' *expressed needs*. Reactive techniques generate useful results for creating solutions and should be used to some extent in many cases, but they include limited opportunities for finding new insights and thoughts outside the pre-conceived expectations. They often miss unspoken, *latent needs*, which are needed for predicting the future usage of offerings and developing highly valuable offerings in the long term. Latent needs can better be captured with proactive, customer-driven techniques, where customers are invited to use their own initiative and find the true value-in-context that the offering can provide. Proactive techniques include working closely with lead users and conducting market experiments, although these methods are not highly defined. The main concept to consider is the *co-creation of value* during the innovation process ("co-creation for others"), which does not have theoretical implications in terms of how and where customers can share their inventiveness. The important point in applying this approach is to adopt a more market-based focus, where instead of possessing information about available solutions and searching for information about various requirements, customers are given solution information and invited to conduct their own need searches. (Witell et al. 2011)

It should be noted that this suggestion of focusing on external actors specifically applies to more radical innovations, as opposed to incremental innovations. Research by Obal et al. (2016) suggests that the new knowledge and perspectives that can be obtained from external relationships are of the greatest value for the development of radical innovations, whereas incremental innovation development benefits more from building on core competencies through internal relationships. While the categorization is not always simple to define, radical innovations (a.k.a. discontinuous innovations or really new products) can be described as results of major technological developments that enable users to do things they have not been able to do before, while incremental innovations (a.k.a. continuous innovations or incremental new products) are direct improvements and modifications of existing products based on minor technology changes (Mugge & Dahl 2013). Based on these definitions, the products of new technological innovations created through research can be categorized as having a high degree of radicalness. Some incremental aspects can also apply as products can improve existing activities as well while enabling new ones, but from a planning perspective, the main focus should be on radical aspects, as those are the sources of the greatest advantages. This focus also better serves the creation of new firms, as existing companies have a significant advantage in exploiting incremental innovations on existing technologies due to already having knowledge and experience of how to exploit inventions in a particular market or technical field (Shane 2004).

Developing and commercializing radical innovations or brand new products faces many unique challenges compared to more incremental commercialization activities. As the technologies are still evolving at the time of market entry, the technological risks and market uncertainties complicate both the developer’s decisions on technology utilization and the customer’s decision to adopt.

Furthermore, identifying customer needs, connecting them to product characteristics and defining customer benefits that the innovative product is meant to fulfill is extremely difficult, as customers are likely to be uncertain about the benefits of the innovation. Another complication is that even if customer needs and preferences can be articulated, they tend to change over time in the process of discovering and experiencing a new technology. (Bohlmann et al. 2013). Thus, market research requires applied methods that can bring out previously unnoticed needs while incorporating a dynamic approach. In this context, Bohlmann et al. (2013) also point out the importance of observing downstream customers and competitors, as changes in customer-of-customer trends strongly affect the evolution of customer needs.

In considering which targets to observe, it should also be considered that the types of customers a new innovation may serve are not easy to define. An initial need assessment can reveal many potential customers from different industries, but classifying customer segments and determining their profitability requires careful study. A possible approach is to choose one sector to target and then potentially build offerings for different segments within that field. Yet, this may be too limiting for innovations based on general-purpose technologies. Creating differentiated offerings for multiple separate fields can provide a significant competitive advantage in the long term. This also reduces risks, as the venture can move their focus to a different sector in case one market faces problems. (Shane 2004). As such, there is merit to a broader market analysis, where plans can be made to serve other types of customers beyond the initial target after some time.

Another aspect that must be considered in market analysis is the competitive environment. Technical and financial competitor analysis may not be possible in the early stages of innovation deployment, but a general assessment of the environment is necessary to understand the context in which commercialization is being attempted. A commonly used method for this is the five competitive forces -model by Porter (2008), which involves five categories of factors that can be used to define the nature of competitive interaction within an industry. The middle force in the model is the rivalry among existing competitors, which is the typical focus of competition analysis, but the model also includes four other forces that can greatly affect the competitive environment: the threat of new entrants, the threat of substitute products or services, the bargaining power of buyers, and the bargaining power of suppliers. This model is illustrated in Figure 1. This analysis should reveal the reasons for profitability in the industry and help with planning strategies. However, it cannot be used to determine *what* the profitability level is, only *why* the level is what it is. Important distinctions to make for focusing the analysis are the industry boundaries, the most controlling forces and recent and likely future changes in each force. (Porter 2008). The five forces model is useful for processing information for strategic decision-making purposes, but obtaining the necessary information, especially concerning change trends, requires the use of additional methods.

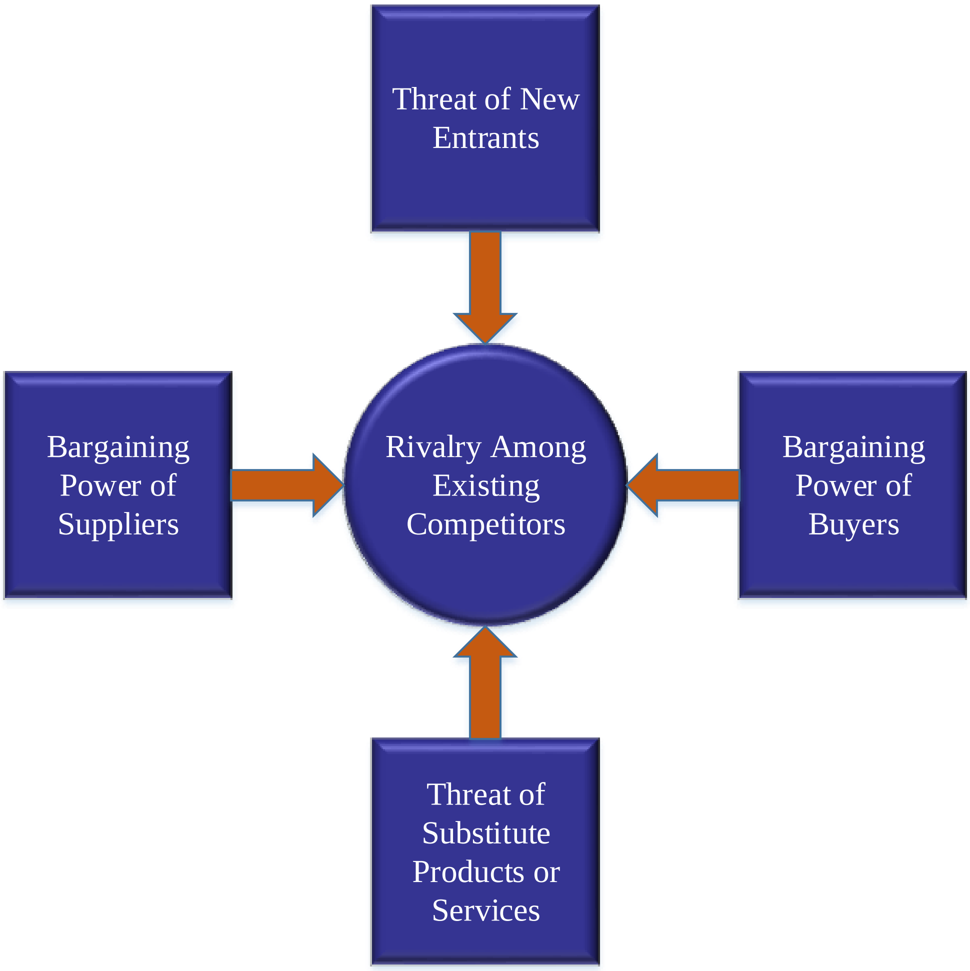

Figure 1 The five forces that shape industry competition (Porter 2008)

In summary, traditional market research methods can provide important information for innovation deployment, but more attention is needed for discovering latent needs and enabling a dynamic approach where plans can be altered in response to changes in the market environment. This requires understanding of how innovations are adopted over time and methods for planning for the future. Some theoretical approaches to this are described in the following subsections.

2.1.1 Diffusion of innovations

Even if a new idea has obvious advantages, getting it adopted is difficult and time consuming. Forecasting this process and planning for it requires understanding of the concept of *diffusion*, which, in the context of innovations, refers to the process in which an innovation is communicated and spread to members of a social system over time. Studies have found that in both commercial and non-commercial cases the adoption of innovations typically follows a normally distributed, bell-shaped curve when plotted over time on an adoption frequency basis. Consequently, the cumulative number of adopters forms an S-shaped curve over time. (Rogers 2003). A general representation of the ideal forms of these curves is presented in Figure 2. It should be noted, though, that this is only one way of defining the S-curve of technology growth. The S-curve represents a natural law of growth, which can be modelled and applied in numerous ways for practically any system evolution or technology forecasting case (Kucharavy & De Guio 2011). Many different mathematical models have been explored in literature (such as Martino 1993), but many of these are unsuited to forecasting radical innovation, as there is little historical data to use as a basis for modelling. The ideal diffusion model is not to be taken as an accurate forecast, but it provides a useful basis for general planning based on qualitative data. It should also be remembered that the ideal S-curve only describes cases of successful innovation, where an innovation spreads to almost all of the potential adopters; in reality, most innovations will ultimately be rejected, causing the adoption rate to level off early and finally nose-dive due to discontinuance (Rogers 2003).

The reasoning for the diffusion model can be attributed to the normal distribution of human traits. In this context, an individual's degree of *innovativeness,* i.e. receptiveness to new solutions, can be identified as a variable trait. Based on this, people are generally classified into five adopter categories: innovators (the earliest 2.5% of total adopters), early adopters (the next 13.5%), early majority (34%), late majority (34%) and laggards (16%). Notably, this system is not symmetrical: this could be solved by breaking laggards into two categories, such as early and late laggards (13.5% + 2.5%), but studies suggest that laggards form a fairly homogenous category. Innovators and early adopters, on the other hand, have quite different characteristics, so they should be treated as distinct categories. (Rogers 2003). The categories are noted in Figure 2.

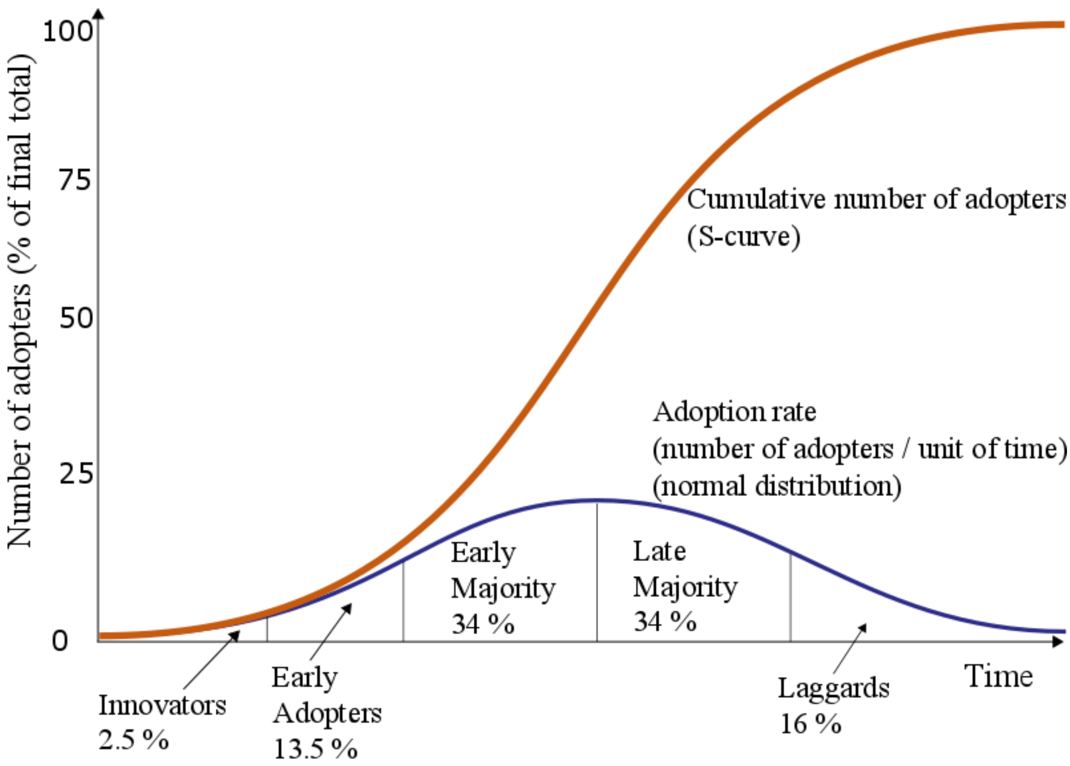

Figure 2 Ideal diffusion model according to Rogers (2003)

The differences between these categories suggest that a different approach should be used when approaching each audience. As such, it is advisable to consider traits of innovativeness in market segmentation and when choosing which people to target with specific types of communications. A typical strategy is one of *least resistance*, where initial communications are focused on the most innovative, and therefore receptive, market segments; however, the least innovative segments are paradoxically often the ones who would have the most need for innovations, so a strategy of *greatest resistance* is also possible through focused targeting. On an individual level, compared to later adopters, earlier adopters are likely to have a greater level of education, a higher socioeconomic status, more social participation and network connections, greater exposure to media and communication channels, greater empathy, rationality and intelligence, and a more favorable attitude toward science and change. On an organizational level, six internal characteristics have been noted to affect innovativeness; however, these variables may have opposite effects depending on whether the innovation process is at the stage of initiation or implementation. These characteristics are defined as follows:

- *Size*, measured in both staff and budget. This may involve multiple dimensions of related variables, though these have not been clearly understood. In general, larger size greatly improves innovativeness, but may slow down implementation.
- *Centralization*, the degree to which power and control are concentrated to relatively few individuals. A higher degree restricts initiation, as top leaders are poorly positioned to identify operational-level problems, but hastens implementation once the decision to adopt has been made.
- *Complexity*, the degree to which an organization's members possess a relatively high level of knowledge and expertise. A higher degree promotes initiation, as members can grasp the value of innovations, but impedes implementation due to difficulties in achieving consensus.
- *Formalization*, the degree to which an organization's members are expected to follow rules and procedures, i.e. the degree of bureaucracy. A higher degree inhibits the consideration of innovations but encourages implementation.
- *Interconnectedness*, the degree to which units in a system are linked by interpersonal networks. A higher degree is always positively related to innovativeness.

- *Organizational slack*, the degree to which uncommitted resources are available. Having more slack resources always promotes innovativeness, especially for innovations that are higher in cost. It should be noted, though, that this variable is typically closely linked to organization size.

(Rogers 2003)

Another important point for forecasting and planning is that while the cumulative adoption curve can be expected to follow an S-shape, the steepness of the curve, or how fast the innovation is diffused, depends on multiple factors. Studies have identified five main variables determining an innovation's rate of adoption: the perceived attributes of innovations, the type of innovation-decision, the communication channels, the nature of the social system, and the extent of promotion efforts. Notably, about half of the variance in adoption rates can be explained by the five perceived attributes of innovations defined as follows:

- *Relative advantage*, the degree to which an innovation is perceived as being better than the idea it supersedes;
- *Compatibility*, the degree to which an innovation is perceived as consistent with existing values, past experiences and needs of potential adopters;
- *Complexity*, the degree to which an innovation is perceived as relatively difficult to understand and use;
- *Trialability*, the degree to which an innovation may be experimented with on a limited basis;
- *Observability*, the degree to which the results of an innovation are visible to others.

(Rogers 2003)

A crucial concept to note is the "critical mass", which refers to a point where enough actors in a system have adopted an innovation so that the innovation's further rate of adoption becomes self-sustaining. As more members of a system adopt, the innovation is perceived as increasingly beneficial to future adopters regardless of its attributes. The key point of the diffusion process lies in the part of the diffusion curve from about 10 percent to 20 percent adoption; after that, the rate of adoption rapidly accelerates, and it often becomes impossible to stop further diffusion even if one wanted to. Some suggested strategies for reaching this point include initially introducing the innovation to relatively more innovative groups within the target system and providing incentives for early adoption when possible. (Rogers 2003)

Of course, the product of the innovation should continue to develop after market entry. While a product or service must fulfill some criteria for initial market entry, attempting to create a fully complete offering for delivery is not advisable. Considering the development of a product or service creates another way of looking at the S-curve, where the increasing number of adopters is based on the increasing number and quality of solutions. Starting with a *minimum viable product* delivered to the first adopters (market entry point), development can be done iteratively in steps to enable the incorporation of customer feedback. One way of defining these steps is to begin with the *earliest testable product*, which is then improved into the *earliest usable product*, and then to the *earliest lovable product*. (Boni et al. 2018). Combining this definition with the diffusion model, the earliest testable product should be able to fulfill the minimum needs of innovators. Their feedback should help build the earliest usable product, which can create enough value to early adopters. Finally, utilizing information obtained from these customers, the earliest lovable product should be good enough to capture the early majority and pass the critical mass of diffusion.

A final point of strategic interest is defining three types of actors that greatly influence the diffusion process: change agents, innovation champions and opinion leaders. A *change agent* is an individual such as a consultant or salesperson who influences clients' innovation decisions in a direction deemed desirable by the drivers of the change. One of the main roles of a change agent is to facilitate the flow of innovations to audiences, which requires an understanding of both the innovation and the needs of the clients, so that they can selectively transmit only relevant information to avoid information overload. Having a credible and empathetic change agent drive efforts to link customers and innovators can greatly enhance diffusion. Change agents should typically have university degrees, but the use of less professional aides can have advantages when contacting targets of lower status. *Innovation champion*s are charismatic individuals within an organization that show support for an innovation, acting to overcome indifference or resistance to said innovation. Radical innovations especially require a powerful individual with a high office, such as a top manager, to act as an innovation champion, or else the innovation is very unlikely to be adopted. Less power is needed for less radical innovations, and in some cases, power can also be substituted by persuasion and negotiation skills. *Opinion leaders* are individuals or organizations that strongly influence the attitudes of other individuals or organizations. The decisions of opinion leaders very strongly affect the success and rate of innovation diffusion, so they should be identified and made the primary targets of most diffusion efforts. The key distinction is that while opinion leaders can mostly be classified as early adopters, they are not usually innovators. The most innovative individuals and organizations rarely have so much credibility in the eyes of others that their actions would have widespread effects. The most influential actors typically have some skepticisms, but if these are overcome, their decision to adopt an innovation can greatly hasten diffusion in their networks. (Rogers 2003)

2.1.2 Scenario analysis

While planning for future developments for an innovation in the context of market research, it is important to note the multitude of different possible future scenarios within the scope of the research. Scenario-based approaches have been widely adopted in product innovation, as scenarios are helpful for revealing the future viability of products, reducing the probability of market failure and enabling the development of appropriate and useful technology that meets user requirements (Hsu & Chang 2009). In the early stages of product development, Hsu & Chang (2009) suggest the development of future situation (exploratory) scenarios, which have four objectives: to envision the use of future systems, to forecast the evolution of the function of the system, to design the product attributes or product characteristics, and to simulate the use of the product. Hsu & Chang (2009) also note that it has been argued that, in a highly uncertain environment, the use of future scenarios to envision and evaluate the use of future products can greatly assist designers in product planning.

It should be noted that scenarios are not synonymous with foresight. Scenarios are descriptions of possible futures, which assume that several key events or conditions take place between the time of the original situation and the time in which the scenario is set. For hypotheses to be considered scenarios, they must satisfy five conditions: pertinence, coherence, likelihood, importance and transparency. A scenario is never an end in itself, but rather should serve as an aid to decision-making by clarifying the consequences of future actions. (Durance & Godet 2010)

Building scenarios is mainly a creative exercise, but to create credible and valuable results, a systematic approach is needed. There are multiple general approaches and methods to scenario planning, but these must be applied according to the situation in which scenarios are created while leaving room for creative freedom. The important point is to gather as many informed judgments as possible and to use participatory methods so that involved individuals may identify the appropriate problems and agree upon solutions (Durance & Godet 2010). A type of a general straightforward scenario building process can be described as follows:

1. Identify and define the universe of concern that you are dealing with, including the point in time to be analyzed.
2. Define the variables that will be important in shaping that future (typically 6-20 variables in complex scenarios).
3. Identify the themes for scenarios (usually limiting analysis to 4 or 6 themes, though fewer or more are possible. Even numbers should be avoided in order to prevent bias for choosing the middle option).
4. Create the scenarios from the themes and write them in a literary format.
5. Review, evaluate and revise the scenarios. Shape the scenarios into a uniform style if deemed necessary. (Coates 2000)

The main issue with scenario analysis is the time required. Conducting scenario analysis or inferences will consume a lot of time and work effort, and scenario knowledge cannot be accumulated over time, as building a scenario for each new application instance requires a new set of data (Hsu & Chang 2009). 12- to 18-month timeframes for comprehensive studies are not rare and an additional year may be required for the distribution and accommodation of the results in an organization (Durance & Godet 2010). Additionally, observed changes in the environment over time can naturally affect aspects of scenarios, forcing re-evaluations. A possible solution for continuous scenario usage is the implementation of a scenario database as suggested by Hsu & Chang (2009), where scenarios are defined as descriptions of potential product use situations containing a series of activities and events through which a user can achieve their final goal. These scenarios can be collected directly through different methods from potential customers or end users, designers, engineers and marketing personnel. Each scenario is analyzed separately to ensure the availability of all important elements of a scenario as defined in terms of "5W1H": *What* happens, *Who* it concerns, *When* does it happen, *Why* does it happen, and *How* does it proceed. The scenarios can then be decomposed and abstracted into higher-level concepts and recorded into a database structure. Afterwards, when considering solution options for any situation, a database search can provide scenario cases for situations with high similarity, which can then be used for case-based reasoning. (Hsu & Chang 2009). This method could allow a more far-sighted approach in innovation development planning as well as more rapid use of scenarios in the long term, but due to needing to gather more data, analyze more scenarios in total and plan the database format, this approach further increases the need for time and resources in the early stage. As such, while elements of this approach are worth considering, it may not be suitable for entirely new ventures.

2.2 Methods for linking technology to market needs

Simply discovering market opportunities through market research does not enable the creation of value before the discovered data is linked to the capabilities of innovators. Distinctions must be made between what is theoretically possible and what is practically viable. This requires deep understanding of the capabilities of the innovating venture and the kinds of configurations that can be made from them, noting the restraints of limited resources and market prospects.

A widely used tool for analyzing internal and external environments is the SWOT framework, which enables the matching of specific internal and external factors, providing a sensible strategic matrix. In this framework, internal factors are defined as strengths and weaknesses and external factors as opportunities and threats. This framework is illustrated in Figure 3. Connecting internal and external factors allows for multiple strategic approaches, often classified into four combinations: maxi-maxi (strengths/opportunities), maxi-mini (strengths/threats), mini-maxi (weaknesses/opportunities) and mini-mini (weaknesses/threats). Triple combinations are also possible. The analysis can be integrated with other methods in order to increase its effectiveness and to create a more powerful strategic tool: examples of this include AWOT, which combines SWOT with the Analytical Hierarchy Process, and BSQ, which is a hybrid of Balanced Scorecard, SWOT and Quality Function Deployment. As an old, purely qualitative technique, SWOT has often been criticized for being overly simplistic, being greatly affected by numerous psychological biases and usually neglecting time dynamism; yet, it is because of its simplicity and ease of use that it is still widely used to some extent in the majority of all strategic processes. SWOT may not be a strong analytical tool, but it is a logical approach that can be used by every organization to generally assess its internal and external environments and adapt its strategy accordingly. (Ghazinoory et al. 2011)

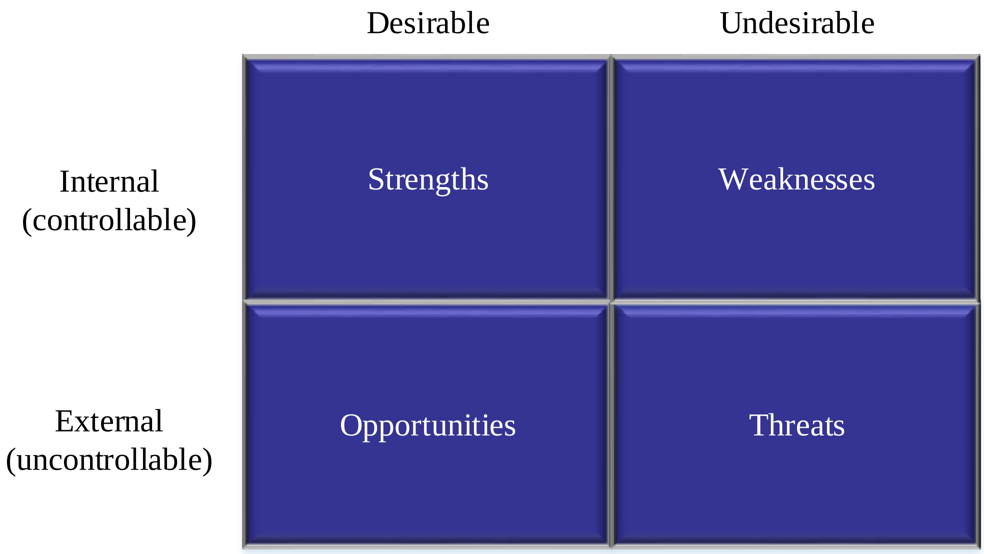

Figure 3 SWOT framework (adapted from Ghazinoory et al. 2011)

Even if technological capabilities and customer needs are understood on a general level, linking them together is not a simple task. Planning development is a complex issue, especially when attempting to ensure future progress in an ever-changing environment. To accomplish this, it is recommended to use structured methods that allow the better defining of the relevant issues. The methods discussed in the following subsections are potential options for improving decision making specifically in the development process.

2.2.1 Quality Function Deployment (QFD)

QFD is a methodology originating from Japan, designed to improve product planning processes. The methodology revolves around utilizing a set of matrices to structure and quantify data in order to show relationships between data. Specifically, QFD is used to translate customer needs into technical specifics that engineers and other knowledgeable persons can act upon. (ReVelle et al. 1998). However, these need statements must be obtained through other methods first; QFD is a data structuring tool used for problem solving and planning, not a tool for collecting customer needs for quality improvement purposes as is often misunderstood (Shillito 1994).

The three most popular QFD approaches are as follows: the *House of Quality* (HoQ), using a single large combined matrix for product design; the *Four Phase approach*, using four HoQ-style matrices at different stages of product deployment; and the *Matrix of Matrices* approach, using 30 interconnected matrices for highly organized planning. These are far from the only possible applications, however. The methodology can and should be applied in many different ways depending on the context and needs of the project and the stages during which QFD will be used. It has been noted, though, that QFD provides the most benefits during the earliest stages of development and is helpful throughout the entire process. (ReVelle et al. 1998)

In any case, the basis of QFD processes is the *voice of the customer* (VOC). This refers to the understanding of the needs of customers. VOC consists of raw data statements collected from customers and the team's processed understanding of that data, which is deployed through the QFD process into product design and commercialization processes. The VOC process is separate from the QFD process and involves obtaining, structuring, prioritizing and measuring customer needs. (Shillito 1994). Obtaining VOC data is dependent on market research activities, but processing the data to obtain understanding can be seen as a separate challenge. One commonly used tool for this purpose is the *voice of the customer table* (VOCT), created by GOAL/QPC as an upstream expansion to QFD, which can be used to expand understanding of the most important needs through six questions: what, where, when, why, who and how (Shillito, 1994; ReVelle et al. 1998). Notably, these are the same "5W1H" terms used in scenario analysis by Hsu & Chang (2009), with the difference that in scenario analysis these questions are directed at visions of what *will likely occur* in the future, whereas the VOCT analyzes situations that a customer *wants to occur*. The expansion is not necessary for all VOC verbatims (Shillito 1994), and it is unlikely that enough information exists for filling the table completely for any need. A type of VOCT table is shown in Appendix 1.

A noteworthy framing to consider when evaluating the VOC is the *Kano Model of Quality*, which divides customer needs into three categories. The first of these is Expected (Basic) Quality, which forms the minimum for market entry. These are needs that remain unspoken unless violated and aspects that are expected to "go without saying". Fulfilling Expected Quality does not increase satisfaction, but lacking these features can lead to extreme dissatisfaction. As these needs are unspoken, they may not be easy to obtain through traditional market research, instead requiring synthesis of observations from customers from varied backgrounds. The second category is Normal (Performance) Quality, which consists of spoken needs. These are the classic VOC statements obtained easily through market research and one-on-one interviews. Normal Quality offers a powerful opportunity for improvement, but these also become easily known by competitors. The last category is Exciting Quality, which involves latent needs that most normal customers are not aware of. Lacking these does not cause dissatisfaction, but having these creates potential for great satisfaction and strong competitive advantages. Some progressive customers of the early adopter type can cite benefits they would like to see, but are rarely able to define how those benefits could be delivered. Finding these needs requires working closely together with potential customers, looking for potential opportunities for more operations in the upstream or downstream processes and identifying trends. (ReVelle et al. 1998)

When choosing the actual QFD approach to use after collecting the VOC, it is important to consider the applicability of different methods in the specific case. Of particular interest for this study is the application of QFD in software development. ReVelle et al. (1998) argue that applying QFD to software is not as straightforward as it might first appear, as some significant differences from hardware and manufactured products (for which QFD was originally designed) require adaptations. ReVelle et al. suggest an approach titled Software Quality (Function) Deployment (SQD or SQFD), which uses a sequence of five matrix models to deploy the VOC, with additional matrices used for forecasting and risk management. The basic SQD matrices are illustrated in Figure 4.

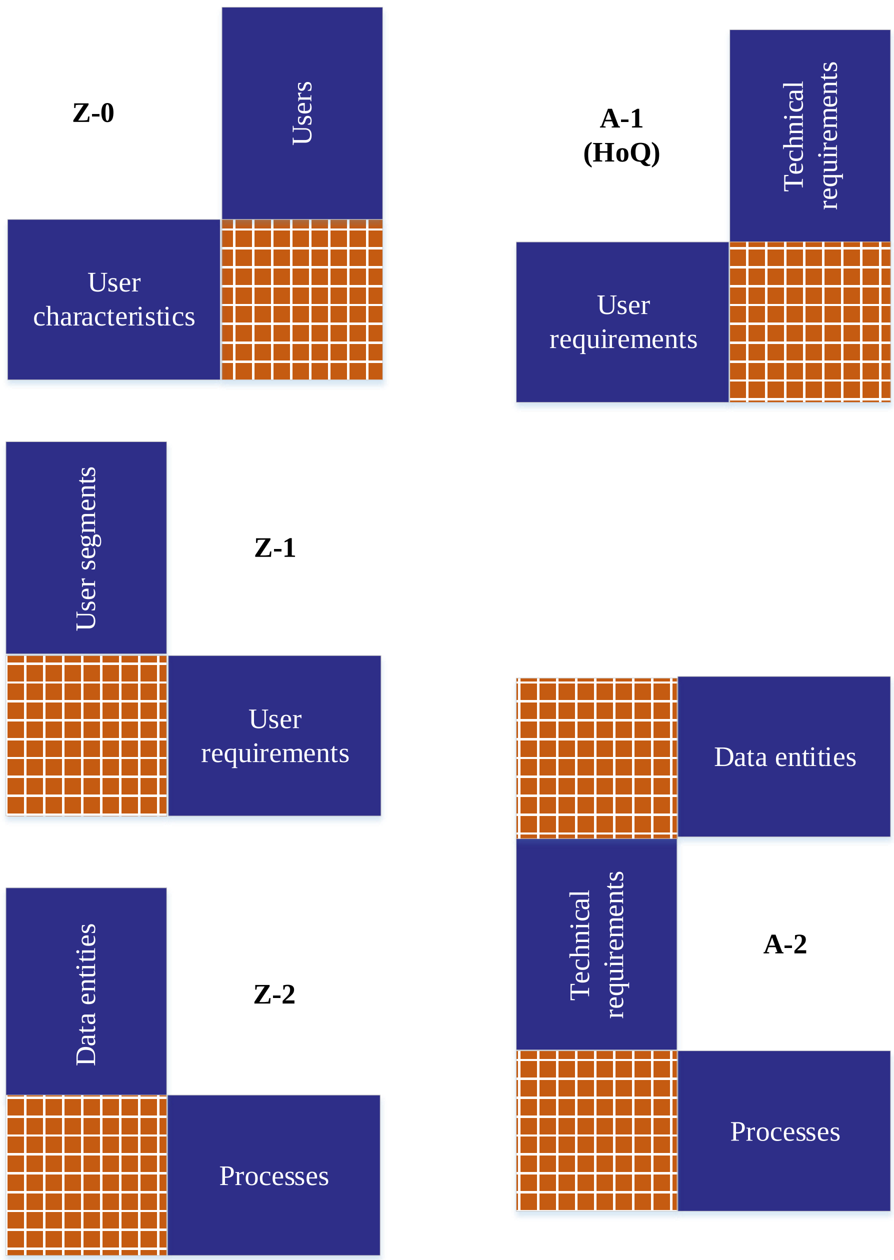

Figure 4 The five basic SQD matrix models according to ReVelle et al. (1998)

The SQD model by ReVelle et al (1998) proceeds in a mostly linear sequence from identifying user segments (Z-0 matrix) to determining and prioritizing user requirements (Z-1 matrix), which are then used in defining and prioritizing technical requirements (A-1 matrix), which are supported by an analysis of required data and processes (Z-2 and A-2 matrices). This process is designed to be performed mostly with internal resources, using already obtained data. Pai (2002) presents a slightly more customer-involved SQFD process, which consists of five steps:

1. Solicit user requirements from anyone who might benefit from the use of the proposed software products and record them in the customer's terminology accompanied by a detailed definition.
2. Convert requirements to measurable technical product specifications in cooperation with the customers.
3. Ask customers to complete a correlation matrix by identifying the strength of the relationships between requirements and specifications.
4. Based on customer survey data, develop and list priorities for stated requirements.
5. Prioritize product specifications based on customer requirement priorities and correlation values between requirements and specifications.

SQD also requires some fundamental changes in QFD progression and terminology. First, when considering resource requirements at any point, material factors are replaced by data and material-based costs are replaced by time. Second, since software development projects must often serve several classes of users and stakeholders, an understanding of who has what requirements and to what extent is necessary. As such, the market segments of users and their different requirement priorities must be defined before attempting to make connections to technical features. User expectations can often conflict or require more resources and time than is available, so it may be helpful to determine the most valuable requirements to focus on by adjusting raw priorities by an adjustment factor such as the number of potential users in each category. Third, the typical early-stage House of Quality connection between *what* needs to be done and *how* it can be done would be premature for software. Instead, the question should be *why* versus *what*. The "*how*s" should be decided later in software design. This also means that considering conflicts between technical requirements, or using the "roof" of the HoQ, is not usually necessary, as conflicts can only exist conceptually at this point. Fourth, simply listing what is needed is not adequate to advance development, so these "*what*s" should afterwards be deployed into models exploring process interconnections and data entity relationships. Fifth, to allow for a balanced understanding of a new technology, the QFD model should be enhanced with additional matrices that can explore possibilities for emerging new concepts and potential failure modes. (ReVelle et al. 1998)

While using QFD methods offers some great advantages, some significant issues must be noted when applying them. As the process aims to change the practices of development, many typical resistances to changes apply, such as lack of time, short-term thinking and lack of support (Govers 2001). Additionally, Govers (2001) lists three categories of common problems in implementing QFD:

1. Methodological problems: difficulties in recognizing customer requirements, interchanging customer requirements with engineering specifications (perspective issue), bad assessment of relationships and the correlation matrices, focusing on metrics rather than processes, expanding charts with too many details.
2. Organizational problems: weak cross-functional co-operation and personnel involvement, motivation issues, failure to integrate QFD activities into the development process.
3. Product policy: issues with defining customers (segmentation), choosing the right offering and using market information (benchmarking).

Another more technical issue stems from the fact that the majority of data in QFD matrices are highly subjective, so using mathematical tools to analyze the data can easily result in mistakes (Shillito 1994). As such, the methods should be used carefully to support planning, rather than following the numerical results as absolute guidelines. Still, if QFD methods are applied successfully, the insights they provide will certainly be of value.

2.2.2 Technology forecasting and roadmapping

Anticipating and driving changes is a key to creating sustainable business. Forecasting of any kind is difficult, but technology forecasting is especially complex, as it deals with new concepts without much historical evidence to draw from (Roper et al. 2011). Technology forecasting encompasses many activities with different names and definitions, but a good basic concept is enabling foresight. In this context, foresight emphasizes achieving desirable futures through policy implementation rather than accepting the future as a given (Roper et al. 2011). This requires a systematic approach to analyzing future expectations and planning actions accordingly. Other notable concepts that can be incorporated into forecasting include competitive technical intelligence, impact assessments, risk assessment and roadmapping (Roper et al. 2011).

Good technological forecasting does not seek to project a single certain future, but rather projects a range of possible futures with different likelihoods of occurring. Also, as the dynamics of the economic and social/political contexts affect the development and adoption of a technology, background forecasts of these areas are needed as well. Applying more than one method and mixing and matching different forecasting techniques helps with balancing strengths and weaknesses and leads to more accurate forecasts. Ultimately, even if the forecast ends up being inaccurate, the process of forecasting itself can reveal valuable information for decision-making. (Roper et al. 2011)

Technology forecasters need information about the technology and its context, which can be obtained from written materials, experts and internet sources (Roper et al. 2011). An important distinction to be made is between *qualitative* and *quantitative* information, which can be defined in multiple ways depending on the context. In the typical context of research material, qualitative data refers to non-numeric, oral, textual or visual material, whereas quantitative data refers to numeric, countable material. In futures studies, qualitative methods have usually been related to heuristic reasoning, while quantitative methods are understood as formal methods, typically mathematical modelling. However, in practice quantitative methods have also been used for heuristic reasoning and qualitative studies have been made in a formal and structured mode. Utilizing both types of information in combination can provide significant advantages for analysis, but doing this can be very challenging, as attention to one type of material tends to dominate over the other in most research cases. (Tapio et al. 2011)

Different approaches can be better used at different stages of analysis. Qualitative approaches are useful for appraising market potential and assessing early buyers and the speed of early growth. In addition to direct customer and expert contacts, many types of secondary sources can be used to infer and estimate market sizes, growth rates and competitor presence on a qualitative level. Quantitative forecasting data can be obtained through extrapolation and simulation mainly based on the number of purchases of the technology, and then used to forecast technology growth using S-curve modelling. These models, however, are only applicable after commercial introduction and are likely to be very inaccurate at first. A good idea is to repeatedly update and apply quantitative models as more data becomes available. (Roper et al. 2011)

Five of the most used forecasting methods are monitoring, expert opinion, trend analysis, modeling and scenario construction. Monitoring is not exactly a forecasting method, strictly speaking, but as it is the most basic and widely used method of gathering information, it is fundamental to almost all forecasts. (Roper et al. 2011). In a business context, all of these methods can be attributed to market research, but the important distinction for applying technology forecasting is how the results are made usable. As Roper et al. (2011) state: “If the forecast is to fulfill its role effectively, the means chosen to communicate the forecast results are as important as the means chosen to conduct the forecast.” Different means can be used to communicate results depending on the characteristics and needs of the decision makers, but the most structured presentations can likely be achieved specifically through the methods of technology roadmapping.

A technology roadmap is basically a graphical representation of technologies, often relating objects like products or competencies and the connections between them over time. Activities required in creating and updating this representation are referred to as technology roadmapping. (Moehrle et al. 2013). Zhang et al. (2016) specify that while roadmapping is in many ways similar to general expert-based foresight projects, it emphasizes visualization and historical data profiling and seeks to add some quantitative methodologies to support decision-making. Zhang et al.

(2016) argue that technology roadmapping can also be useful for bridging together expert-based foresight and quantitative-based foresight projects to obtain unique benefits from both, though they note that mostly expert-based qualitative methods are generally still preferable due to the high costs, inflexibility and high IT requirements associated with quantitative techniques.

Many types of roadmaps exist in terms of purpose and format, and the structure of roadmaps and the processes used for developing them need to be suited for each particular purpose and organizational context (Phaal et al. 2013). An important distinction according to Beeton et al. (2013) is between *goal-oriented roadmaps*, which seek to exploit core competencies and develop internal sources of knowledge to support strategic planning, and *exploratory roadmaps*, which seek to access external sources of knowledge and broaden the organizational knowledge base to support foresight. In the case of exploratory roadmaps, multiple alternative roadmaps can be built for different scenarios, but the goal of a scenario-based roadmap should be to use interim points to analyze and solve each possible branch separately to establish a development road (Geschka & Hahnenwald 2013). In any case, Phaal et al. (2004) note that many of the benefits of roadmapping are derived from the roadmapping process, rather than the roadmap itself, so the steps of the process form an important dimension to consider when planning the type of roadmapping to be done. A study by de Alcantara & Martens (2019) presents numerous cases of technology roadmapping uses, implying that roadmapping is an important and growing trend in overall technology forecasting.

The most common (generic) roadmap format comprises a number of layers and sub-layers of different perspectives, such as market, product and technology, with the evolution or migration of the business charted within each layer. Key linkages are mapped between terms across layers and used to show the mechanisms of technology push and market pull. (Phaal et al. 2013). A type of generic roadmap is illustrated in Figure 5. Some other types have been presented by Phaal et al. (2004), though accompanied by a warning that graphical forms can present information in a highly synthesized and condensed form, so the roadmap should always be supported by appropriate documentation.

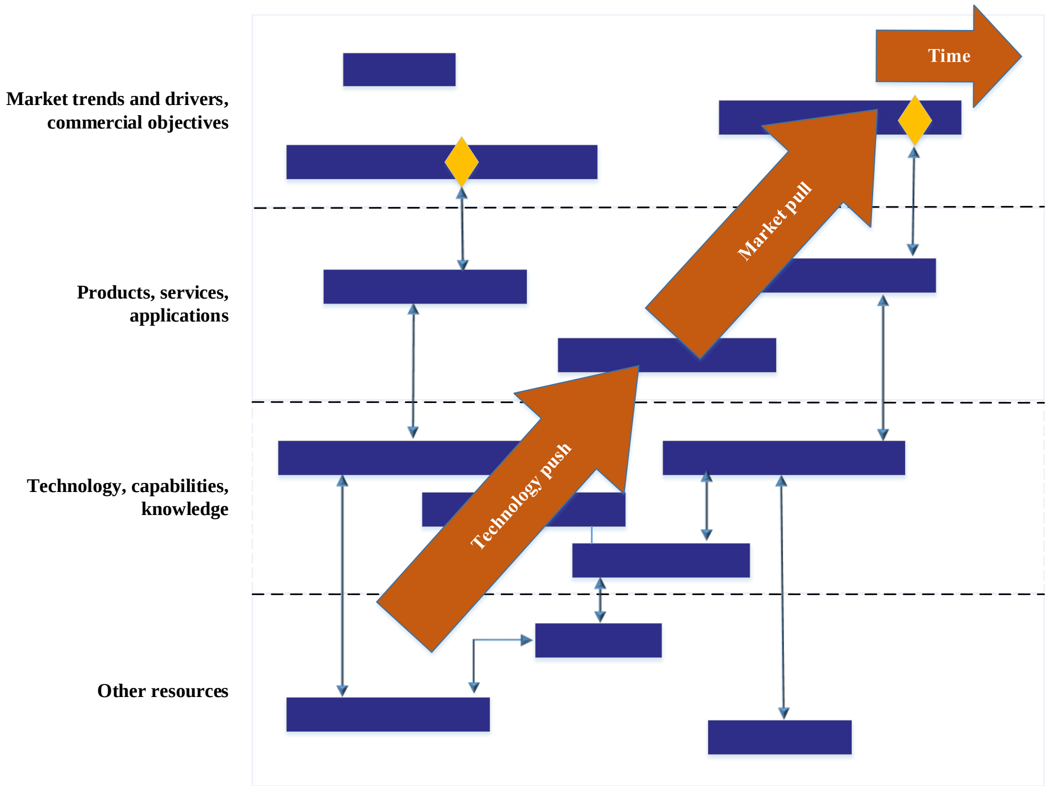

Figure 5 A generic technology roadmap architecture (adapted from Beeton et al. 2013)

Roadmapping has been recognized as a critical activity for adding business value, particularly to a software product. It is a flexible technique that can be used to support strategic and long-range planning by exploring and communicating the dynamic linkages between markets, products and technologies over time. A good roadmap provides a clear focus for solution development. However, there are some problems associated with roadmapping. Determining the beginning and end of the roadmapping process can be difficult, and enough time must be allocated for solution planning from a strategic perspective to avoid compromising long-term plans. Understanding customers' activities is necessary for defining market trends and commercial objectives, yet acquiring this knowledge and disseminating it to all necessary personnel can be problematic. One related challenge is to determine customer's activities at an appropriate level of abstraction: mapping at a too general level may not reveal any new information or assist in further work, but highly detailed definitions may not be possible when planning in the long term. (Komssi et al. 2015). Geschka & Hahnenwald (2013) note that creating scenario-based technology roadmaps is an especially laborious process, which does not even produce concrete plans to work with, only providing a basis for subsequent specific planning. Gerdsri (2013) also notes that if technology roadmapping is to be implemented to guide strategic planning and operations on an ongoing basis, plans must be made and resources must be allocated to ensure the roadmap is continuously updated.

2.3 Studies on university spinoffs

Universities are major source of new knowledge, yet the transfer of this knowledge into industry is not a simple process. Traditionally, the role of bridging the gap between university research and commercial companies has been played by industrial R&D departments and laboratories; however, the tough competition in modern industry has caused downsizing and shifting to more profitability-based focusing in these labs (Peng 2006). Without a new method of technology transfer, many early-stage, uncertain university inventions would remain unlicensed and unfunded as large, established companies are unwilling to invest in the development of these inventions (Shane 2004). Moreover, when licensing does occur, typically only one company will be interested, leaving universities with very little room to bargain on the terms of the agreements (Shane 2004). This is but one of the reasons for the recently increased interest in university spinoffs (alt. spin-off, spinout).

There have been multiple definitions as to what constitutes as a university spinoff. Shane (2004) defines a university spinoff as “a new company founded to exploit a piece of intellectual property created in an academic institution”. Pattnaik & Pandey (2014) list four defining characteristics of a university spinoff as follows:

1. The parent organization from which the innovation emerges has to be a university or academic institution.
2. The output that is a university spinoff has to be a separate legal entity and not an extension or controlled body of the university.

3. The new entity has to exploit knowledge produced from academic activities or academic pursuits.
4. The spinoff should be aimed at profit generation and the commercialization of technology.

University spinoffs can be compared to new high tech -based start-up ventures, but they have some distinctly different qualities. Attempting to establish a competitive firm in a traditionally non-commercial environment comes with many unique challenges, which will be further discussed in section 2.3.2. However, university spinoffs also have some notable advantages compared to many other actors. Researching and developing new technology in a university environment allows different types of approaches and strategies for business creation compared to the commercial scene. For example, Shane (2004) suggests that university spinoffs can greatly benefit from using general-purpose technologies, as they offer multiple market applications to exploit depending on the situation, while established companies have trouble identifying how to benefit from these. This is supported by research by Clarysse et al (2010), which found that the broadness of the scope of technology is positively correlated with the success of university spinoffs and negatively correlated with the success of corporate spinoffs.

The development processes in university environments may be slower than in commercial ones, but this does not mean worse financial performance. Research by Ortín-Ángel & Vendrell-Herrero (2014) suggests that while university spinoffs under-perform economically compared to other new technology -based firms in their early years, their productivity growth is faster, usually reaching equal levels in 2-3 years and surpassing others significantly in about 5 years. This suggestion is based on data from Spain between 1994-2005, so the actual numbers likely differ depending on the context, but Ortín-Ángel & Vendrell-Herrero believe the general results can be extrapolated to other European countries. The research suggests that the reasons for this are that university spinoff founders generally have fewer managerial skills but greater experience in creating knowledge, and that university spinoffs more commonly use embryonic, cutting-edge technologies which are still developing; alternatively, Ortín-Ángel & Vendrell-Herrero state that their results could be partially explained by academic entrepreneurs being faster and better learners than most others.

University spinoffs are still relatively uncommon, but multiple studies have found them to be quite important in many ways. Pattnaik & Pandey (2014) and Shane (2004) list at least the following three benefits: enabling or enhancing (local) economic development, improving the commercialization of university technologies and helping universities with their major missions of research and teaching. Shane (2004) also adds that university spinoffs are disproportionately high performing companies, which usually generate more income to universities than licensing the technology to established companies would. A literature review of university spinoff studies by Almeida (2018) shows that despite them only having become more prominent somewhat recently, there already exists a great diversity of scientific articles in this field, though many aspects have only partially been considered and could benefit from deeper study.

For the purposes of this study, the main concerns are in the actual process of spinoff creation. While the spinoff-favoring policies and conditions in universities can naturally help to foster spinoffs in some ways, these may be difficult to affect. Also, while much study has been conducted about the effects of different university policies on spinoff success rate, findings by Berbegal-Mirabent et al. (2015) indicate that no similarly intensive combination of conditions seems to yield more spinoffs compared to any other, implying that different strategies on the part of the university can lead to the same results. As such, rather than finding ways to change university behavior, the focus of spinoff creation teams should be the processes and actual actions leading to spinoff creation and beyond. There have been multiple suggestions for modeling the spinoff creation process, notably some of the earliest models by Ndonzuau et al. (2002) and Shane (2004), which were given a new “critical juncture”-based perspective by Vohora et al. (2004), which was further modified into a multi-stage model by Pattnaik & Pandey (2014). All of these models are presented in Figure 6.

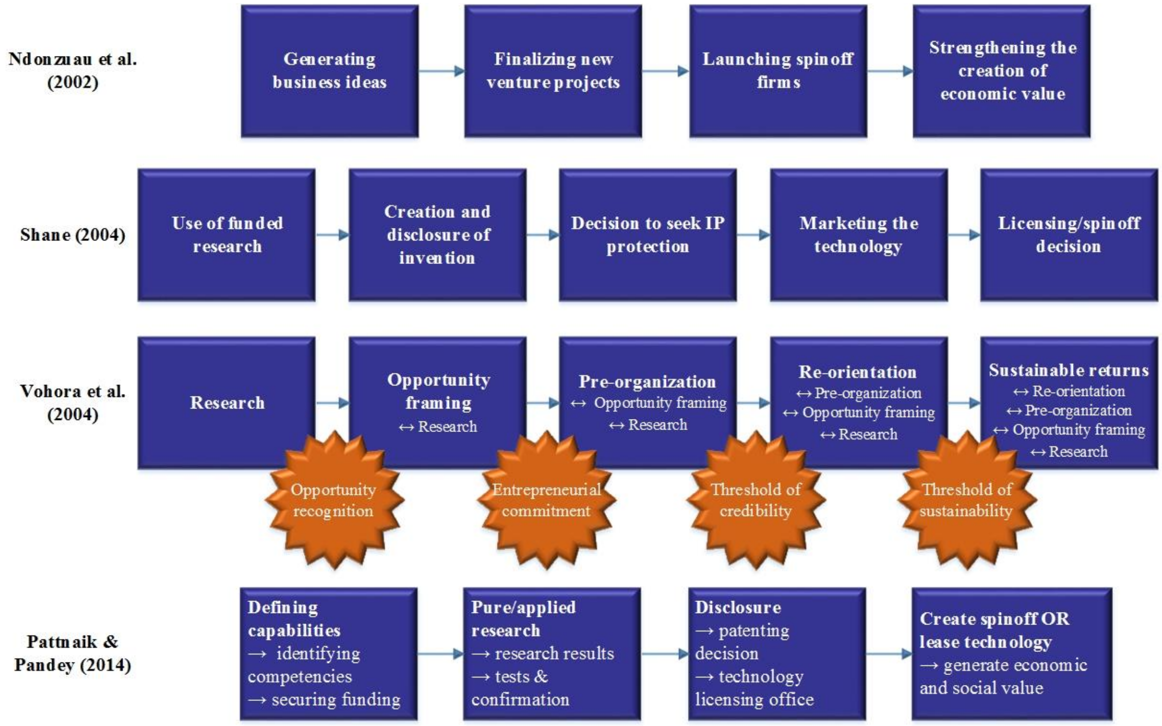

Figure 6 Models of spinoff creation

Aside from the model by Vohora et al., the stages are all relatively similar, with the largest differences being the relationships and timing of research, securing funding and planning business. The model of Ndonzuau et al. does not include research as a part of the spinoff process, rather implying that the results of academic research can be used to launch a new venture process as-is when an opportunity is recognized. They identify funding as an important issue to be considered in later stages of business creation, but do not include this in the model. Shane's model assumes university research is sufficiently funded to allow the refining of research into inventions, which can serve as basis for seeking additional financing and planning business. Finally, Pattnaik & Pandey suggest that funding should be secured based on identified competencies, so that a financial perspective is already considered before research begins. All of these three models are based on a mostly linear progression of events, although the Shane model ends at spinoff formation and considers product development a separate process to follow, while the other two include this in the value creation process, assuming the initial offering already delivers enough commercial value to enable business actions.

The model by Vohora et al., however, while still based on transitioning between progressing phases, suggests non-linearity and includes re-evaluating earlier results at each stage based on newly discovered information. This model includes product development under re-orientation, assuming that significant changes to the initial offering are usually necessary before the business can receive sustainable results. Shane (2004) also supports this idea, stating that most university spinoffs are founded at a “minus two stage”, meaning they need to conduct much further development of their technologies after their firms are founded. Shane (2004) further states that even if the spinoffs are based on relatively more mature technologies, they still have to undertake additional development to make the technologies appropriate for the commercial environment. Due to these differences in modeling the evolution of research innovations into commercial technology, this process needs further examination both before and after spinoff formation.

2.3.1 Product development in university spinoff context

While some technology always exists at the start of a spinoff project, creating a product involves additional technical development for multiple reasons. While technologies created in university research can have great potential, customers do not usually buy raw technology, but rather products and services. As such, university technology needs to be changed into a form that fits the expectations of commercial actors and makes external stakeholders comfortable. Customer feedback during the process will also reveal problems or provide information about needs that necessitate further changes. Product development can also create new intellectual property that can be protected e.g. by patents, which are a valuable source of credibility. (Shane 2004)

Yet, many university spinoff founders underestimate the importance of product development due to lack of knowledge about the practices and processes of product development. This knowledge must be learned, as new technologies require many changes to transform them into products. These changes can include improving performance, enhancing robustness, adding supporting technology, scaling up, increasing ease of use and changing mechanisms and architecture. There is much technical and market uncertainty associated with spinoff projects, as even after a prototype has been developed, no one can be certain whether the founders are capable of making further required changes and whether the product can ultimately satisfy a real need in a cost-effective way. To overcome these uncertainties, spinoffs need market research and customer interactions to obtain information necessary for selecting which applications to pursue. (Shane 2004)

Still, despite the evidence suggesting the importance of following market signals, a.k.a. employing market pull strategies, most university spinoffs employ the technology push -approach, where they create the best technological solutions they can and then expect those to bring commercial success. Many fail to realize that success is dependent on meeting customer needs, not on having the best technology. Customers need to be convinced of the value of the products and services. Successful spinoffs incorporate assessments of customer needs into the product development process, at least to some extent. (Shane 2004)

It must be noted, though, that often employing technology push instead of market pull may not be due to lacking understanding, but rather a matter of preference. An example of this was the ultimately successful LUT spinoff Mevea, where the managers were aware that a market pull approach may have been more profitable, but the company mostly followed a technology push approach as it felt more rewarding. Their initial research had not included much market perspective, and when the initial prototype software was built without customization options, which was then found to be considered highly important by customers, commercial interest was lacking. However, the company was able to use the initial technology soon afterwards as a basis for building tailored solutions according to specific requirements expressed by a few key customers, which then served as references for further improving the base product to a more generally attractive one over time. Despite a difficult start from a financial perspective, the founders continued to dedicate their efforts to building the company because they were motivated by the desire to be at the forefront of technology. Monetary profits were a secondary objective. (Eskola, interview 11.12.2018)

Research also suggests that especially in B2B markets, start-up firms, including university spinoffs, can greatly benefit from collaborative product development, which closely involves customers or other types of users in various ways. Empirical studies on these customer involvement processes are still rare, however, so it is difficult to define how this can be accomplished. (Laage-Hellman et al. 2018). Based mainly on a case analysis of Oxeon, a successful Swedish university spinoff, while also noting other case studies, Laage-Hellman et al. (2018) list five crucial aspects to note in collaborative product development for a start-up: the need to include customers early, the choice of application areas, the mutuality of the process of partnering, the external networking role, and the internal organizing relating to the ambitions for external customer interactions.

Early interactions of information exchange and user-testing provide important insights for directing development activities while also preparing potential customers for buying later when deliveries can be made. However, these customers need to be quite innovative themselves, as otherwise they are likely to be hesitant and rather ask the start-up to come back later when it has a finished product to offer. Choosing an application area is necessary to begin operations and this choice has large strategic implications and major consequences for both product development and customer relationships. This decision should be based on perceptions of the future network, though as with any forecasting, this involves much uncertainty. The choice of collaboration partners is also of great importance, and must include the consideration of the fact that the firm also needs to be chosen by these partners. As resources are scarce, there is a limit to how many partners can be worked with in parallel, yet concentrating on only one customer in an application area can be a risky strategy. If partner relationships do not develop as wanted, some customers may be likely to terminate partnerships and possibly partner with another actor, so this risk must be noted. Finally, different external network roles involve different challenges depending on the firm’s positioning in business networks, so these factors require full attention from management. Enabling effective management in this regard requires relational capabilities. The development or acquisition of these capabilities must be considered when planning how the start-up should be organized. In the earliest phases, company founders typically devote much of their time to managing external relationships to achieve this. However, as the company grows and the founders’ time is taken by other management duties, their relational capabilities must be transferred internally to other parts of the organization. (Laage-Hellman et al. 2018)

In summary, while universities provide a great environment for creating new and innovative technologies, further developing these into products is a difficult yet necessary challenge. Many of the difficulties can theoretically be overcome through researching markets and interacting with potential customers, especially in the context of collaborative product development. Yet, following this type of approach is still somewhat rare due to differences between the natures of basic technological research, which university researchers are mostly used to, and market need –based product development. As such, acquiring the knowledge and expertise necessary for product development should be a key task in spinoff formation.

2.3.2 Challenges in spinoff formation

Although research on university spinoffs have found them to be important in many ways and have great potential for success, integrating commercial firm formation into university environments still faces numerous unique challenges. While university spinoffs have often proven to be effective ways to transfer knowledge into industry, they also have notable negative aspects from the university perspective, which can impede their creation from the very beginning. Shane (2004) notes three central problems in this aspect: lack of widespread faculty support for spinoff activity, the adverse effect of the commercial model on traditional university goals, and conflict of interest problems. According to Shane (2004), studies show that most university faculty do not support spinoffs, as critics charge that they adversely affect open dissemination of knowledge, reorient activity from scholarly goals toward commercial goals, and cause conflicts of interest and potential financial abuse as related parties focus their efforts on maximizing private gains instead of advancing research. Shane (2004) also notes that getting involved in spinoff creation is a risky activity for universities, as the costs are typically very high, much additional learning and training is required and the market prospects are very unclear. The statement by Ortín-Ángel & Vendrell-Herrero (2014) of university spinoffs reaching the same productivity compared to non-academic ventures in 2-3 years only accounts for time in actual operation; depending on a multitude of factors, the process required to prepare a spinoff for launch can take a wildly varying amount of time, during which costs will also naturally be incurred. This implies that earlier data on the costs of university spinoff formation likely cannot be generalized to most cases, forcing assessments to be made on a case-by-case basis.

From the perspective of the spinoff project itself, there are multiple great hurdles that are not simple to overcome. Vohora et al. (2004) have identified four critical junctures in the process of spinoff formation, presented earlier in Figure 6, each of which demands special attention. The first of these is *opportunity recognition*, which can be defined as the transitional phase between research and commercial opportunity framing, involving matching an unfulfilled market need with a solution that satisfies that need that most others have overlooked. Universities and academics may possess significant technological know-how, yet they often lack knowledge of how to serve markets. As such, it is proposed that "without developing, acquiring or accessing the capability to combine scientific knowledge with a commercially feasible offering that satisfies an unfulfilled market need, academic scientists would not be able to proceed towards commercializing their technologies." The ability to overcome opportunity recognition can be identified as "the ability to synthesize scientific knowledge with an understanding of markets that is enhanced significantly by higher levels of social capital in the form of partnerships, linkages and other network interactions." (Vohora et al. 2004). In other words, interactions with external actors, such as potential customers, are a vital source of information needed to overcome this challenge.

The second critical juncture is *entrepreneurial commitment*. This phase must be overcome in transitioning from opportunity framing to pre-organization. In order to realize mental visions and intentions into a business venture, actions must be taken to bind a venture champion to lead development. However, it can be very difficult to find an individual with the needed entrepreneurial capabilities and willingness to commit in the university environment for multiple reasons. The social capital of academics is often limited to networks within academia, with few role models to follow. They often lack business experience and feel little faith in their abilities to work in a commercial environment. On the other hand, they may also lack self-awareness over their personal limitations, leading them to take on too many responsibilities and not delegating the work properly. Using a surrogate entrepreneur is not simple either, as the limited social capital of inventors makes it difficult to find suitable individuals, the lack of resources makes it difficult to offer rewards and incentives, and the common inability of academics to relinquish control of their ideas to anybody else impedes the process. Case studies have shown that not resolving these conflicts completely and simply proceeding with the academic inventor working on the spinoff part-time leads to deficiencies, weaknesses and inadequacies that restrain entrepreneurial activity and the amount of value created. (Vohora et al. 2004). Shane (2004) adds that spinoffs founded by complementary venture teams perform better compared to ones not founded by complementary teams, as involving business founders provides the spinoff with management and industry knowledge and expertise in product development, all of which university inventors tend to lack. Shane also notes that having a full-time entrepreneur as a founder improves performance, as their signaled commitment generates support among potential shareholders and their time dedication enables them to accomplish all necessary activities when the spinoff grows and develops.

The third critical juncture is *the threshold of credibility*. Transitioning from a pre-organization stage venture to a fully operational business requires an initial stock of resources, with the key resource being finance. Identifying the required resources to be obtained when sufficient financing is available is another problem, though these cannot be acquired in any case without either some initial financial investment or co-optation of resources through networks. Either way, in order to proceed, the main issue at this juncture is the necessity of credibility for acquiring seed finance and human capital for forming the entrepreneurial team. It is suggested that this critical juncture is also related to the acquisition of key customers for the spinoff, as this similarly requires proving credibility. The capability to show the ability to create and deliver value and the commitment to doing so is vital to success. (Vohora et al. 2004). The case of the LUT spinoff Mevea is a concrete example of this challenge, as their initial loan application was denied on the grounds that while their technological expertise was clear, the team did not seem to have enough business expertise. The company only managed to overcome this challenge thanks to the dedication of the founders, who initially worked without pay until they managed to create sustainable business. The acquisition of key customers at this difficult stage was still possible due to multiple large companies having been involved in guiding the research well before the spinoff was formalized, so personal connections had already been established and the companies were aware of the basic ideas behind the technology. (Eskola, interview 11.12.2018). This case shows that involving potential customers and partners in the initial research and project development phases can be highly beneficial for enabling the development of the capability to show credibility.

The fourth and final critical juncture is the *threshold of sustainability*. At this juncture, the spinoff requires the ability to re-configure existing resources, capabilities and social capital as situations change and evolve. Significant transformations are often necessary to enable the generation of returns in a sustainable manner. Yet, developing this ability can be very challenging. University spinoffs have been found to be able to develop their non-financial resources and social capital relatively easily, but configuring these into competitive capabilities faces problems. The processes of re-configuration require much coordination and communication, but spinoffs often find their abilities lacking in this regard. Large and established companies have policies, procedures and routines in place that simplify decision-making and reduce uncertainty and complexity in leading change, but university spinoffs must first assemble their formal and informal structures and devise policies and routines to obtain the capability to adapt. Weaknesses inherited from decisions made in earlier development phases may be too difficult to resolve at this stage. Spinoffs are likely to stagnate at this juncture because of resources becoming depleted before sustainable results are achieved. As such, foresight of future issues from both internal and external viewpoints in earlier phases of development is vital for preparing a venture for facing this final critical juncture. (Vohora et al. 2004)

Ultimately, while methods exist for overcoming these challenges, the underlying issue may be the unwillingness of academics to focus efforts on entrepreneurial tasks. Creating business is very different from academic research, which is what most academics are used to. In all of the listed junctures, the main issues seem to be related to lacking communications and commitment. As illustrated by the notion that working with a technology push -approach is felt to be more rewarding than with market pull, determining tasks to perform independently is commonly preferred to asking external actors what they would like to be done. While some level of independence is advisable, as academics do often have superior knowledge of technology, market signals must be accounted for in decision making when creating business. This paradigm shift can be a major challenge in spinoff formation, but can likely be helped by active networking and utilizing consultants.

2.4 A combined framework for supporting technological innovation deployment planning

Based on earlier studies, it can be summarized that the main challenge in deploying a radical technological innovation is in creating an offering that the first potential customers will perceive as attractive enough to invest in. When approaching this problem with a strategy of least resistance, the minimum viable product for market entry can be defined as the earliest testable product. Since the earliest adopters theoretically form a definable category of innovators, consisting of approximately 2.5 % of potential customers (Rogers 2003), the theoretical goal for the earliest product can be set as the ability to fulfill the basic needs of these customers, who are also the most potential partners for product testing. This definition should support the initial prioritization of development. The next goal should then be to use methods of co-creation to refine the offering to the earliest usable product (Boni et al. 2018), which by adopter definition fulfills the needs of the next 13.5 % of customers (Rogers 2003). Their feedback should enable improvements leading to the earliest lovable product (Boni et al. 2018), at which point the critical mass of diffusion can be exceeded and future development priority can and should be shifted to incremental improvements and supporting the business strategy.

Naturally, if enough time and resources were available, using comprehensive market research projects, following long-term development plans and delivering high incentive offerings to strategically chosen opinion leaders (Rogers 2003) could allow relatively low-risk innovation deployment. This is rarely the case, however. Specifically in the context of university spinoffs, resource availability is very limited and support for commercial projects is lacking (Shane 2004). Additionally, as identified as the first critical juncture “opportunity recognition”, academics usually lack the necessary capability to combine scientific knowledge with a commercially viable offering (Vohora et al. 2004). To overcome this challenge, a framework is needed to create the ability to synthesize technical expertise with an understanding of markets and enhance understanding through interactions. Using a structured framework should also support more accurate project planning, which contributes to the capability to demonstrably create and deliver value, helping with overcoming the threshold of credibility (Vohora et al. 2004).

A common approach for enabling the synthesis of technical and market expertise in product development is using matrices based on QFD methodology to deploy the voice of the customer (ReVelle et al. 1998; Shillito 1994). However, the questions of how to obtain the VOC statements and how specifically they should be analyzed are not simple to answer. The basic solution to prioritizing technical development based on customers’ stated importance levels is sound, but when there are multiple categories of potential users, solving conflicts requires additional adjustment factors. Some type of additional method is likely also required to actually integrate the activities and results of QFD into the product development process.

With these points in mind, this study suggests utilizing the base logic of QFD for supporting the early-stage planning of innovation deployment, but supplementing it with other methods for obtaining, structuring and analyzing information. This approach is specifically designed for cases where it can be assumed that the actors involved have a high level of technical expertise but understanding of markets is initially very lacking. Based on research on the topic of university spinoffs, this is typically the case in most spinoff projects, so this should at least be generally applicable in this context. The methods should support the acquisition and analysis of all relevant market information and the combining of this information with expert understanding of the developing technology.

The following suggestion is a multi-step approach to evaluating potential development paths primarily based on QFD, but incorporating elements of SWOT analysis, the five competitive forces and theories on the diffusion of innovations through adjustment factors. Forecasting, scenario analysis and roadmapping are also suggested to support process integration and progression planning. A general summary of the suggested process is presented in Figure 7, with more detailed descriptions following in section 2.4.1.

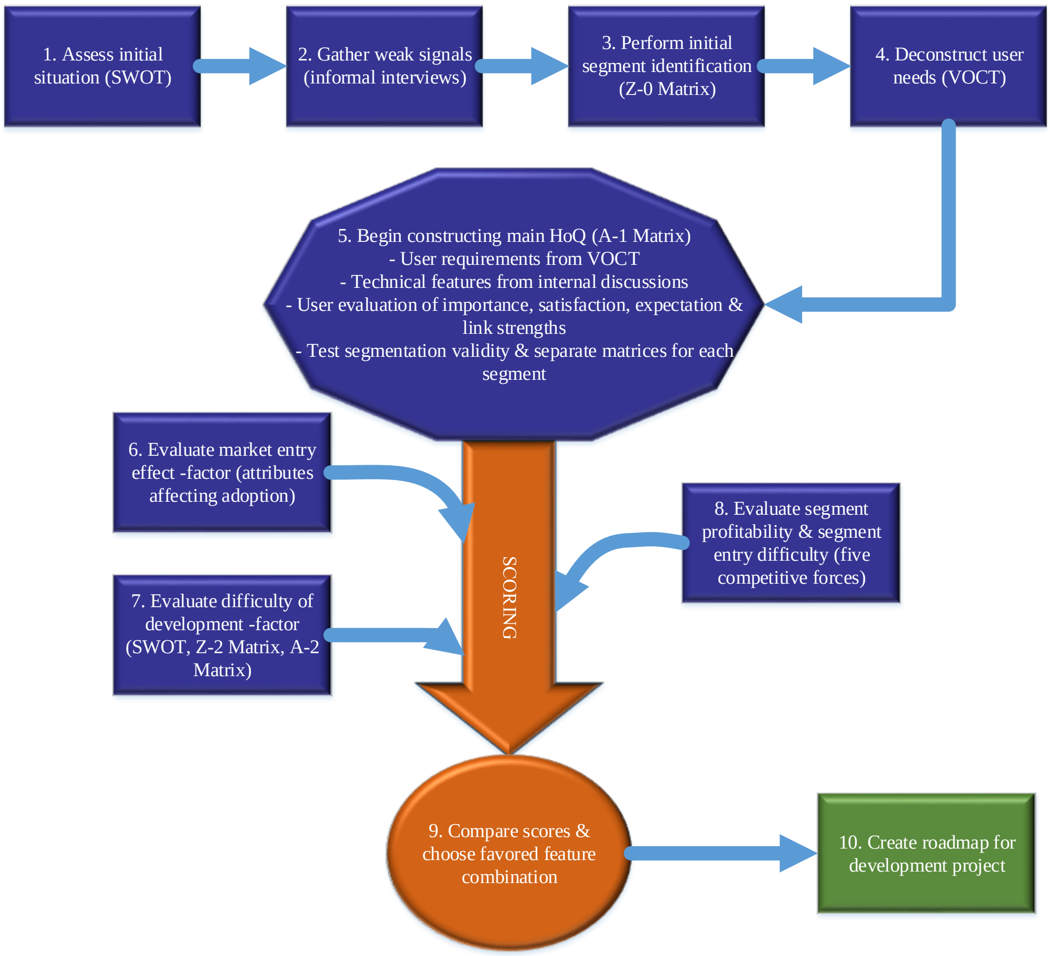

Figure 7 Suggested technological innovation deployment planning process

2.4.1 Suggested deployment plan framework building process

When the goal is the deployment of a new technology, the basic concept and potential fields of application for said technology should be understood at the start of the process. The first step should therefore be clarifying the initial situation, which can be supported by the SWOT framework (Ghazinoory et al. 2011). Specifically, the analysis of strengths and opportunities should reveal some highly potential customers (maxi-maxi –approach). Weaknesses and threats are also important to note for future planning.

The next step should be using informal interviews to gather weak market signals to be used as initial VOC statements. By providing minimal information about the new technology to identified potential users of the innovation and then listening to their thoughts, it should be possible to discover needs that could be fulfilled with the new offering once developed. Setting up these discussions may prove challenging, but university spinoff projects can use the common respect for university research to their advantage. This approach should reveal normal quality needs as well as some extent of excitement qualities depending on how much information is shared. Basic qualities may be difficult to obtain directly, but they may be possible to uncover through analyzing the topics of discussion that come up. Another method could be soliciting views of likely future situations before introducing the new technology at all. This could better reveal basic qualities while also providing important information for beginning scenario analysis in the background. Introducing the technology first is likely to steer the discussion in the direction of wanted futures, rather than expected likely scenarios; yet, it may be necessary to at least partially introduce the new concept before a customer is willing to share their thoughts. Some forecasting can also be done internally if project personnel have enough knowledge of industry trends.

Once some potential customers have been interviewed, an initial identification of customer segments should be performed. At this stage, this will mainly be an exercise in logical deduction, but it can be supported by using the “Z-0” matrix, where individual customers (customer companies in business-to-business markets) are attributed to a list of characteristics (ReVelle et al. 1998). Customers within the same segment should naturally be similar in most ways. However, since a general technology may be targeted towards multiple different fields, where the same functions can serve different types of users, this may be difficult to apply. In addition to typical characteristics, it could be useful to find connections between users and the operating functions they perform that are related to the new technology. The important points in this segmentation are the functions that the offering must serve and the value creation potential within these functions. Some customers may belong to multiple segments based on functions; for example, some machine manufacturing companies can also provide maintenance services, while many companies may be focused on only manufacturing or only maintenance. As such, specific operating units within a customer company could be considered separate customers with differing value creation potential. The innovative characteristics of companies (as defined by Rogers (2003)) could also be included in this analysis format for later use, but as these can vary within a segment, they should not be used as a basis for segmentation, only as factors when deciding first targets for testing partners.

The VOC statements should be further analyzed before attempting to create a HoQ matrix. Using the voice of the customer table (as presented in Appendix 1) to deconstruct customer needs is one potential method for accomplishing this (ReVelle et al. 1998). The identified segments should serve as demographics. The purpose should be defining reworded data and demanded quality so that they can serve as basis for listing user requirements in later matrix analyses. Quality characteristics offer additional guidance for product development. A suggested addition to the basic VOCT is the Kano quality distinction (ReVelle et al. 1998), where each need statement is categorized as a basic, normal or excitement quality. This evaluation may be difficult at this stage, but should still be considered and later updated. A similar table could also be used to support scenario analysis, as the basic questions used for deconstruction are the same, only with a different perspective.

At this point, enough data should be available to begin constructing the main HoQ (“A-1”) matrix. This common tool of QFD (ReVelle et al. 1998) should allow the evaluation of technical feature priority, once all necessary factors have been accounted for. User requirements should be obtained from the VOCT, after which internal discussions can create potential solutions to be presented as technical requirements to fulfill user needs. An important consideration is the level of detail at which technical solutions are defined; specifically for software products it would be too early to consider how something is accomplished, so solutions should be presented as what-level, general solutions that can be offered in the future once the software is further in development (ReVelle et al. 1998). Once these lists are complete, an internal evaluation of linkages can be performed. For further validation, potential customers should be interviewed again and asked to make evaluations in two steps. First, user requirements should be evaluated in terms of importance (scale 0-5), satisfaction level with currently available solutions (scale 0-5) and level of expectation from new technology based on Kano definition: must-have (basic), want (normal), nice-to-have (excitement), or no need (case where a need is present, but current solutions fulfill the need at a completely satisfactory level). Second, the linkages between user requirements and technical requirements should be evaluated. As typically suggested for QFD, the values should be 0 for no linkage, 1 for low linkage, 3 for medium linkage and 9 for high linkage. For the sake of simplicity in the survey format, these can be replaced for example by symbols or numbers 0-3 and later converted to the suggested values for analysis. No answers to linkages should be expected for requirements that are considered unimportant, but if these are obtained, they should be included in the analysis. In both steps room should be left for additions and comments. Once results are obtained, the variance of answers within a segment should be checked to test the validity of the segmentation and make changes when necessary. Average evaluation scores can then be calculated for each segment and recorded in a "Z-1" matrix for reference. Finally, basic HoQ matrices can be mostly constructed for each segment.

Next, additional adjustment factors are needed for the HoQ matrices before final scores can be calculated. Common adjustment factors in QFD (as presented by Shillito (1994)) are *improvement ratio*, which tells how much an offering must be improved from the current level to be attractive based on competitive analysis, and *sales point*, which is an evaluation of how much the planned improvements would influence sales. However, these factors cannot be calculated this way for a new offering that does not yet exist. When the goal is creating a minimal early product that would be attractive enough to the first customers, a better method could be adjusting technical feature scores based on their effect on the expected rate of diffusion. As stated earlier, Rogers (2003) has noted five attributes that have a great effect on the rate of adoption: relative advantage, compatibility, complexity (reversed as simplicity), trialability and observability. As such, using a matrix to evaluate all potential features based on these factors is suggested for creating *market entry effect* factors to be used as adjustments in the main HoQ. Since this factor is meant to replace the sales point factor, the scale should be similar; Shillito (1994) suggests that a factor of 1.5 means significant market leverage, a factor of 1.2 means some leverage, and a factor of 1.0 means status quo. A possible evaluation would therefore be to value each attribute between 1-5 and calculate the factor as follows:

$$\text{Market entry effect} = 1+(\text{average of attributes})/10 \tag{1}$$

Simplicity, trialability and observability should all be possible to evaluate internally and compatibility can be assessed based on interview data. Relative advantage is difficult to determine, as the potential of the new offering compared to existing solutions will depend on many factors; however, since data has been obtained about satisfaction levels in relation to customer needs, it can be assumed that needs that are currently less satisfied have more room for improvement and therefore features that can fulfill these needs have greater potential relative advantage. However, since these are evaluated for needs rather than solutions and the evaluations differ for each respondent, including this in this adjustment factor is not possible. As such, this evaluation is suggested to be applied separately as an *improvement potential ratio,* which can be applied separately to adjust the importance of needs similarly to the improvement ratio as suggested by Shillito. Normally, this ratio is calculated by dividing future goal level rating by current level rating while both are evaluated on a scale of 1-5 (Shillito 1994), but in this case, a future goal level is not determined, a current level of 0 is possible, and a current level of 5 indicates that new solutions for this need are unnecessary. Yet, if a level value of 5 is assumed as a basic goal in all cases, the following formula is suggested for calculating this factor:

$$\begin{aligned}
&\text{For current level 0: Improvement ratio} = 1.90 \qquad (2)\\
&\text{For current level 1-4: Improvement ratio} = 1+(5/(\text{current level}))/10\\
&\text{For current level 5: Improvement ratio} = 1.00
\end{aligned}$$

With these rules, most needs will receive factors between 1.125-1.5. Currently completely unfulfilled needs are slightly emphasized with a factor of 1.9, as these are attractive targets for new innovations. Completely solved needs are given the lowest factor of 1.00 as these do not require new innovations. These needs could also be given a factor of 0 to remove them from further analysis, but in rare cases it may be possible that these statements contain basic needs that must be answered to some extent regardless of the level of current solutions. Now adjusted importance scores for each need can be determined simply as a multiplication of stated importance multiplied by the improvement potential ratio, with two exceptions. In the case that the Kano quality of a need is evaluated as “no need”, even if the current level is not evaluated as 5, the adjusted importance should be reduced to 0. On the other hand, if a need is evaluated as a “must have”, the adjusted importance should be increased to 10 to emphasize the priority of solutions targeted at this need.

Technical features should also be evaluated in terms of estimated *difficulty of development*. A possible scale is 1-9, where a value of 1 means a feature that requires barely any further development, while a value of 9 means that developing the solution would require nearly impossibly high amounts of time and effort. Shillito (1994) would rather suggest a scale of 1-5, but this is in the context of improving existing products; for brand new innovations, the evaluation may need a wider scale. While the exact costs of development are likely impossible to determine for new innovations, higher development difficulty should relate to greater time and resource requirement and therefore higher cost, making this an important factor in determining project profitability. Features included in the final scoring must naturally be possible to develop in the given project timeframe with resources that are available or can be made available in time to allow development. This estimation is difficult, but the product developers should be able to at least determine relative difficulty levels between different features. This can also be supported by considering the SWOT analysis, where strengths should reduce difficulty and weaknesses will increase difficulty. In the case of software products, features require specific processes, which require specific data entities. As suggested in the SQD model by ReVelle et al. (1998), this analysis can be supported by the “Z-2” and “A-2” matrices, where processes are first connected to data entities, and then both are connected to technical features. These matrices themselves do not include the timing of data availability, so this must be included in additional documentation for project planning. One additional point for consideration is how features may affect each other: some features may become less difficult to develop after another one has been completed. Normally, this analysis is done as a part of the main HoQ, but ReVelle et al. (1998) noted that since software features should not be presented on a highly technical level, scoring these connections will likely not be possible. It may be possible to make these connections between processes in the “A-2” matrix, but accounting for their effect in the final scoring will be difficult to model. Leaving these connections out of the analysis may be a necessary simplification.

As scores must be calculated separately for different segments, additional total score adjustment factors are suggested for each segment. The first of these is *segment profitability.* This should be based on expert evaluations on the financial potential in the target markets, supported by the five competitive forces -analysis (Porter 2008), specifically the bargaining powers of customers and suppliers. A consideration here should be that based on innovator adopter categorization, the first testable product, which is the goal of this process, should theoretically be able to capture 2.5 % of the target market. Determining this profitability factor numerically will be very difficult, however, as it must be comparable between segments and to cost factors as defined by development difficulty estimates. More research is required before generally applicable guidelines for this can be suggested. The second segment factor is *segment entry difficulty*, which estimates how difficult it will be to obtain customers in the target market. This estimate can be supported by the five competitive forces –analysis (Porter 2008), specifically the levels of threats and rivalry. In the case of business-to-business markets, one potential consideration in this estimate could be the six characteristics that affect innovativeness in companies as noted by Rogers (2003): size, centralization, complexity, formalization, interconnectedness and organizational slack. If companies within a segment are somewhat similar in these aspects, these could be used to form a score with through a matrix; however, if these variables are highly varied within a segment, these likely cannot be used for segment score adjustment.

Another mathematical approach could be through feature development difficulties: since the Basic Qualities in the Kano model form “the minimum for market entry” (ReVelle et al. 1998), the base market entry difficulty could possibly be defined as the total sum of development difficulties for features that are needed to fulfill all Basic Quality needs for a segment. This factor also requires further study before generally applicable suggestions can be made. The two factors should be relatable to each other, so using the same scale would be ideal.

Once all factors are determined, the final calculations can be made. Using the score calculation methods of the HoQ, technical features can be ranked for each segment. With the suggested factors, the calculation of scores for each cell in the matrix is suggested to be performed as follows:

$$\text{Cell score} = \text{linkage value} * \text{market entry effect} * \text{adjusted importance} \quad (3)$$

The total score for each feature can then be calculated as a sum of the cell scores for that column. These scores can then be normalized to percentages for clearer comparisons. Finally, to account for difficulty, a *value index* should be calculated. According to Shillito (1994), if the relative cost of developing a feature can be assessed, a value index can be calculated as relative percent importance (in this case the normalized column score) divided by relative percent cost. Since the difficulty of development is used as a substitute for cost in this model, relative percent cost is substituted by relative percent difficulty. Calculations can be made separately for each survey sheet, after which the average feature scores and can be calculated within each segment and further into value index. Features with higher value should naturally be prioritized, but when the goal is to create a minimum product for target entry, a more focused plan could be created by finding potential combinations of features and ranking them, rather than only ranking individual features. In this case, the total development difficulty should be minimized and not allowed to exceed segment profitability; however, the feature combination must fulfill all Basic Quality needs and create a total score that exceeds segment entry difficulty. Once viable combinations have been determined, new score factors can be created for them. As development difficulty defines the costs of creating features, *profit factor* can be defined as segment profitability per the total difficulty of development for a feature combination. Meanwhile, the greater the total score for a feature combination, the more attractive it should be to customers, and therefore more likely to succeed in market entry. As such, a *risk factor* can be determined as total score for a feature combination per segment entry difficulty. How the combinations should be ranked based on these factors depends on strategy in terms of how much risk is allowed for expected profits. Ultimately, the ranking of different feature combinations could be supported by a multi-criteria decision making method such as the analytic hierarchy process (AHP), though how exactly this should be implemented cannot be suggested before further research.

Finally, once the favored approach has been chosen, a basic roadmap should be created for the project. Based on scenario analysis and internal assessments of development time necessity and the timing of resource availability, the connections between the layers of resources, capabilities, products and markets (as used by Beeton et al. (2013)) can be mapped over time. This can be presented in the generic technology roadmap format, shown earlier in Figure 5. Connections in both directions should be noted: while the more obvious direction is using capabilities to create products for markets, if the customers are involved in the creation process, their feedback can contribute to advancing product development and offer new knowledge for developing capabilities. The visual representation should be as clear and simple as possible to serve as quick reference, with accompanying documentation providing more detailed descriptions of strategic plans. In the case of spinoffs, these plans should also include specific measures for overcoming critical junctures in spinoff creation. One point to note in following the plan is that if the project is failing, shifting development to a different viable configuration that includes features already developed could allow a second attempt, if enough resources are available.

It should be noted that while the progression between steps is mostly linear, many evaluations are very subjective and based on assumptions, so some iterative improvements should always be made when new information is obtained. If one step is affected by new information, all steps it is connected to must naturally be updated as well. The model should therefore be built so that the data is connected to ensure updates are reflected in results and to make updating as easy as possible.

2.4.2 Weaknesses and limitations in the framework

The goal of the suggested process is planning only the creation of the earliest testable product, which can then be refined through methods of co-creation. While the information recorded as a part of this process will be valuable in further development as well, the scoring only applies up to the minimum product stage. As most adoption decisions after this point will likely be largely based on existing customer references, the importance of the attributes that affect adoption rates will no longer be as high as in the initial market entry phase. Also, while Basic Qualities are necessary to prioritize for market entry, Exciting Qualities will quickly become the main drivers of competitive advantage. The ranking of features to develop created during the suggested process may therefore eventually become almost completely reversed. An entirely new evaluation system may be necessary to guide further development.

One issue with the scoring system is that it only evaluates strategies that target one segment. Depending on how segments are defined, this may be somewhat too limiting for general-purpose technologies, since they could allow simultaneously building differentiated offerings for different sectors without greatly increasing resource needs. This could be more profitable and less risky in the long term. An additional consideration could be that after the favored feature combination is chosen, it can be compared to the needs of other segments to see if they can be fulfilled to a satisfactory degree without major changes or additions. If so, a secondary product could be created for a different sector. However, this could severely complicate overall planning.

Even with these limitations, though, the process is highly time-consuming. Obtaining required information and evaluations is highly dependent on both internal scheduling and the availability of external actors (i.e. customer contacts and possible financial experts). Project time and resource constraints may prevent the full utilization of the framework. Also, as the process aims to create a simple, defined plan to be followed, it does not have a high level of dynamism. Some information may become outdated during development, and while iterative improvements are suggested, the models used do not include a check to ensure this is done frequently enough. The longer the project takes, the greater this issue becomes.

Ultimately, the framework is simply a tool for supporting decision making, not an absolute guidance system. All used information and evaluations are subjective, especially ones concerning visions of the future. Some practical limitations and environmental factors not included in the analysis may need to be taken into account when finalizing plans.

3 CASE BRAIN

The BRAIN-solution is conceptually a software-based technological innovation, which is based on a modeling and analyzing technology developed at LUT over the course of over 15 years. The core technology has been used for a variety of purposes within the university, such as designing and analyzing rotating structures and their support components. Noting the emergence of new markets thanks to developments in IIoT (Industrial Internet of Things) and the increase of public incentives to develop business out of research, plans were made in 2018 to develop BRAIN into a software product for industrial use, which could ideally be commercialized by forming a spinoff company.

3.1 Initial state of the BRAIN project

The core project group in charge of development consists of a Doctor of Science appointed as the project champion, a professor leading the laboratory where the technology is developed, and a business expert in charge of leading market research. In addition, multiple researchers and students are used when possible to advance different aspects of the project.

According to a preliminary study, the developed core algorithms and interface format should be protectable as a new IP, which can be licensed, sold or developed further. As such, the solution can be considered as a proprietary technology, which implies a great potential value. As noted by Shane (2004), evidence from multiple sources suggests that possession of patents strongly increases the likelihood that a university spinoff can raise capital, as patents provide externally verifiable evidence of a competitive advantage. Whether the algorithms should be licensed, sold or commercialized through a spinoff is still under consideration, but as the technology is very general-purpose, evidence discussed in section 2.3 points to the option of further development with spinoff plans having the highest potential for bringing this technology to the commercial scene, if this is financially viable.

At this time, the project is facing the critical juncture of opportunity recognition as described in section 2.3.2. Some business plans have already been considered, such as offering the software as a service or forming strategic partnerships with machine manufacturers, but the desired business model is yet undecided and organizational goals have not been set. The market needs to be fulfilled are still rather unclear. Further framing is required before product development can be advanced and business plans can be formalized.

Technically, a functional proof-of-concept exists as the program code can already be used for some limited purposes, but it is not refined enough to be confidently demonstrated. The planned next step of the project group is therefore to obtain, understand and utilize information on customer needs in guiding the creation of a more attractive PoC, which should be further developed into a prototype software product by the end of the year 2020. The first goal is to plan the creation of an early-stage software that enables market entry and allows commercial testing, while also gathering information for planning development in the long term. To enable following through with this approach, as market signals are still weak, scientific methods of market analysis and mapping linkages between needs and technology should first be used in order to obtain the necessary information and document it for use throughout the project.

3.1.1 BRAIN technology overview

BRAIN is classified as a “physics model based rotating machinery vibration analyzer and interpreter”. It is an approach based on a design and analysis software used in machine development processes, which can provide important insight on a measured machine’s operational performance by applying the “digital twin” methodology.

There have been multiple definitions and types of application for digital twin methodology, but the basic concept revolves around linking a pair of a physical product and a virtual product created for visualizing, simulating and optimizing said physical product through digital design. Traditionally, the physical and virtual products have been separated, but recently, e.g. due to developments in Internet of Things (IoT) technologies, the bridge between these products seems to be narrower (Tao et al. 2018a). While IoT is not easily defined, it involves deeper and more intelligent interconnectivity between things or objects utilizing new enabling technologies such as sensor networks, mobile Internet, semantic data integration, cloud computing etc. (Vermesan et al. 2014). In the context of machinery, the key advantage is that by using IoT technologies, data can be collected in real time and products can communicate and collaborate with each other and with intangible services on the internet. Some of the potential benefits of the digital twin approach include the ability to adjust the behavior of the physical product based on 'recommendations' made by the virtual product and making the virtual product more accurate to the physical product by utilizing measured data signals. (Tao et al. 2018a)

The core idea of BRAIN is to use data from the design phase of a rotating machine to create a physics-based model using an in-house developed RoBeDyn (Rotor-Bearing-Dynamics) software code, which has various ready developed bearing and support models, enabling the creation of an accurate simulation. The software can then include measured vibration and temperature data signals from an actual operating machine and run comparisons to discover valuable information about the state of the machine, including potential issues that could lead to breakage. The initial software code already contains several analysis functions that can calculate and visualize the following:

- Rotor plotting
- Free-free vibration frequencies and modes of the rotor system
- Campbell diagram i.e. natural frequencies and damping ratios as a function of the rotation speed
- Steady state responses due to the unbalance load
- Threshold speeds of rotor dynamic instability
- Plotting of rotor whirling modes

- Rotor deformed shape plotting
- Transient time integration.

However, more functionality is still needed for BRAIN to have commercial potential. Development is ongoing, currently focused on building software that can be run independently from the simulation program that is still used for running the code at the moment. The next features to be developed will be decided based on market research results.

3.1.2 Potential applications

The RoBeDyn-software code has been used in the machine design phase to model and analyze multiple different industrial rotating machines such as paper machines' rolls, high-speed electrical machines, compressors and turbines. Based on how widely the software code has proven to be useful used in earlier studies at LUT (such as Pyrhönen et al. 2009), it is proposed that it should be possible to apply this technology to many types of rotating machines, such as electrical motors, compressors and turbines. Because of this wide applicability, the BRAIN solution could be tailored to serve machine manufacturers, maintenance companies, industrial machine end-users or combined networks of these depending on the results of market research.

In general, the digital twin methodology has been mainly used for the design, operation, fault diagnosis, predictive maintenance and performance analysis of complex systems such as industrial engines, turbines and power generators (Tao et al. 2018a). Yet, current solutions for the prognostics and health management of complex equipment, related to operation and maintenance, are still largely detached from virtual models, suggesting significant improvements could be made by applying digital twin solutions (Tao et al. 2018b). However, the high costs of implementation currently limit applicability to high-cost and major equipment (Tao et al. 2018b). One possible solution to this issue could be reducing the data intensity by simplifying fault detection and classification through focusing analysis to a limited but scalable number of factors, such as vibrations, temperature etc., optimized by means of data clustering (Yunusa-kaltungo & Sinha 2017). This method could create a potential advantage for BRAIN. On another note, Tao et al. (2018a) suggest that digital twin could also be used as a basis for a new product design methodology that is suitable for less complex consumer products as well, providing another market opportunity.

Based on these observations and the results of earlier studies at LUT, the initial assessment of the potential advantages of BRAIN, conducted by project personnel, has determined three major focus points for concretely enhancing industrial activities: maintenance, research & development and operation. The technology could create significant value within each of these categories, but the mechanisms of value creation differ.

Maintenance costs can be reduced, as parts no longer need to be measured and changed periodically; instead, sensors can be set up for continuous monitoring and maintenance can be initiated when parts are determined to be actually damaged or worn out. Additionally, the advance prediction of breakage using simulation models can help to avoid unexpected production cuts, which are a major source of financial losses.

Research & Development can increase their product quality and reduce time-to-market for new and tailored products by utilizing the software to analyze products immediately after manufacture. BRAIN could allow machine developers to efficiently deepen their understanding of their new products and determine their usability, swiftly making revisions where necessary. This could lead to competitive advantage and economic benefits through increased product reliability, longer life cycles and faster new product deployment processes.

Operation can be optimized through precisely determining limiting operational factors such as the threshold speeds of rotor dynamic instability. In addition, reduced time for problem identification, made possible by the model-based approach, could enable extending the operational time through changes in machine use. These actions could help to maximize production efficiency and improve maintenance scheduling.

The most easily quantifiable financial benefits can be assumed for large industrial users, such as power plants and paper factories, where BRAIN can likely exceed the cost-efficiency of earlier solutions. However, in the short term, these benefits mainly only arise from savings in maintenance, as noteworthy increases in production efficiency and quality cannot be expected until the offering is further developed using measured data and accumulated experience. Meanwhile, the first version of BRAIN can most likely immediately be used to create value for R&D to some extent, but the exact benefits are practically impossible to determine before the solution is adopted and tested by industrial partners.

3.1.3 Uncertainties to be addressed

The main issue for concern at this stage lies in the fact that the most obvious economic benefits have so far been found with industrial machine users and maintenance providers, yet the current software is mainly designed for machine design. BRAIN could potentially create attractive value for manufacturers as well, but this is difficult to estimate and prove before further research. More information must be gathered about the potential uses of the solution in commercial firms and the financial benefits that can be associated with them. As competitor analysis has not yet been performed, the scope of competition in this field is also still unclear, but it seems that solutions with some similar usability for manufacturers are being provided. Therefore, entering this market likely requires more innovative, customer need -based differentiating development.

Due to this difficulty in assessing value creation potential, it is also very difficult to define potential revenue streams. As long as it remains unclear how the technology can create value, it is impossible to determine what kind of business model could be used to deliver that value in a profitable way. As such, decisions concerning the business model to be used cannot be made at this stage.

Another concern is the fact that the modelling software requires data from the machine design phase, which may not be easy to obtain in all cases. The model requires inputs such as physical dimensions and material composition, which are often not found in the databases of machine users, as they have traditionally not had need or interest for this kind of data. As was stated during an interview at a turbine manufacturing company, “Customers are usually not interested in machine specifics, as long as it works.” Since users rarely make efforts to obtain or record data necessary for BRAIN, data must be obtained from other sources when needed. Large industrial users could potentially negotiate agreements to arrange the delivery of the necessary data, but then a separate system needs to be put in place to import this data directly into the software. This approach may also not work for smaller customers or users relying on a large variety of manufacturers, as setting up the system requires much effort and manufacturers may not be willing to share detailed information about their designs. Another approach would be to collaborate with machine designers to utilize data from them directly, but this requires more interactivity from the BRAIN developers. Additionally, scaling the offering would likely be slower with this approach, as incorporating data from multiple partners into a single offering requires careful attention to data handling due to confidentiality regulations. These problems may be slightly lessened if the solution is initially offered for the use of machine manufacturers and scaled up from there, but as stated earlier, entry into this market could prove difficult.

Finally, performing the necessary measurements of machines requires monitoring. The most critical machines are already commonly monitored, but expanding the BRAIN offering to a wider variety of machines requires the utilization of compatible and reliable sensors. In this scenario, the costs and technical limitations of sensors may become decisively important factors for the success of BRAIN. As such, strong partnerships with sensor manufacturers may be crucial during later stages of the project. If this path is chosen, developing and maintaining these partnerships will require strategic attention. The long-term financial potential of solutions for machines that are currently not viewed as critical enough to monitor must be thoroughly evaluated before choosing this path.

3.2 Applying methods for the BRAIN project

When applying the framework to case BRAIN, the first step was performing a current state analysis based on evaluations made earlier in the project plan proposition, which was used in applying for funding, as well as discussions with the project champion. A SWOT analysis was then done on a general level. The results are shown in Table 1.

Table 1 Case BRAIN initial SWOT analysis

Strengths	**Weaknesses**
• Unique machine dynamics approach • Light operation • Access to university research • Wide applicability	• Small team • Slow development • PoC running through licensed software, no own solution yet • No existing partnerships • Limited access to magnetic bearing data
Opportunities	**Threats**
• Simple modelling to improve machine design quality and agility • Advance prediction of breakage can create savings • Continuous monitoring & fault diagnostics useful for large systems • Cheap sensors to enable continuous monitoring for more machines	• Proving value to manufacturers is not easy • Data availability issues are likely • Analysis accuracy is low if available measurements are inaccurate • The increasing use of active magnetic bearings may eliminate many targeted issues

Next, some potential customers were identified and approached for interviews. Identification was based on the usage of machines where the developed technology could be applied, with slight preference given to larger companies. Contacting was done via e-mail and direct phone calls targeted mainly at technical experts within the selected companies. The subject was introduced as a university project, which seemed to affect responses very positively, as none of the contacted parties outright refused an interview. Interested parties were also sent a small overview presentation, which included information about the project team and some planned applications. Representatives from 12 different companies were interviewed at least once during the 6-month study period, though more companies were contacted, and interviews will still be held for some time by other researchers. A larger number of contacts would have been ideal, but this sample still provided valuable information for further development. All discussions were recorded as memos, which were used as reference for the next steps. The interviews were between 30 to 60 minutes long and mostly unstructured, though the following key topics were included:

1. Overview of the BRAIN concept
2. Current state of vibration analysis in the company
3. Visions of possible needed improvements in the future
4. Estimates of potential financial benefits achievable through BRAIN
5. The readiness of the company to develop their business through the opportunities provided by BRAIN.

Notably, future visions were not collected before introducing the BRAIN concept. This approach was useful for quickly opening discussions, though it was not ideal for finding Basic Quality needs. However, the overview of the concept was done on a very general level and without involving the technical developers. This way the discussion could be moved to the current state of the customer companies without direct relations to development plans, enabling the later analysis of unspoken needs based on descriptions of current processes. Estimates of financial benefits were difficult to collect due to the broad scope of the concept, but some comments were useful for estimating market potential for different segments at a later point. The stated development readiness of companies provided an idea of their levels of innovativeness, which is an important factor in deciding the first partners for testing.

During these interviews, it became clear that the BRAIN technology could be used in two different contexts: in supporting machine design through suggestions based on quick modelling and data obtained from cases analyzed in the past, or in improving machine lifetime performance through diagnosing developing issues early based on comparisons between measured data and simulated models and then suggesting optimal maintenance plans. As these contexts require different approaches in many ways, two different concepts for BRAIN software emerged. These were designated as a machine design support solution and a machine upkeep support solution. The word "upkeep" is not perfectly descriptive, as this concept includes dimensions of both maintenance and operative decision-making and control, but it was deemed sufficient for documentation at this stage. When the potential benefits and threats discussed in the interviews were summarized, they were divided for these two concepts as shown in Table 2.

Table 2 Interview summary for the two BRAIN concepts

<table>
<tr><th></th><th>Machine design</th><th>Machine upkeep</th></tr>
<tr><td>Value factors</td><td>- Speeding up product development
- Competitive advantage for manufacturers through quality factors:
• Less noise
• More even quality for production machines
- Lighter operation compared to current modelling tools increases usability
- Enabling simple manual updating for models can improve the utilization of experience-based information
- Finding limiting values for designs brings especially great value for tailored product development
- Helping create products with longer lifetime</td><td>- Improving machine lifetime performance
- Predicting machine behavior and improving controllability
- Increasing automation for fault diagnostics
- Improving models over time through machine learning
- Improving in advance maintenance scheduling</td></tr>
<tr><td>Threats</td><td>- Active magnetic bearings offer substitute solutions
- Functioning competing solutions available and in development
- Direct financial effects are quite limited, value can be difficult to prove</td><td>- Lack of data may create challenges:
• End users lack design data
• Manufacturers lack in use data
• AMB data largely protected and difficult to obtain</td></tr>
</table>

Based on these responses, an initial assessment of segments divided the interviewed companies into three different categories: machine manufacturers without upkeep service offerings, machine manufacturers with upkeep service offerings and other users. The last category included companies that used rotating machines for some type of value creation purposes, such as paper production. Manufacturers without upkeep service offerings would naturally mainly have needs connected to the development assistance concept, while other users should mainly be concerned with upkeep support. Manufacturers with upkeep service offerings could benefit from both concepts, though they may have different priorities for each function.

However, this segmentation is only based on the interviewed companies and cannot easily be extrapolated to the industry as a whole. More accurate segmentation could have been possible by involving a greater number of companies and utilizing the "Z-0" matrix as suggested, but this was not possible due to the time constraints of this study. This segmentation was still considered accurate enough for this stage of the project and would be used in further analysis.

Using this segment definition, statements of needs were gathered from the memos into the VOCT format shown in Appendix 1. As expected, some cells could not be filled, but the format did support the deeper analysis of needs and allowed the recording of logical deductions for future reference. The Kano quality distinctions were marked as initial estimates, which would be improved after a second round of interviews. Future expectations for scenario analysis could not be recorded in the suggested table or database formats due to the low number of statements that were received from this perspective, so these were listed separately for potential later analysis when more information could be obtained.

Based on the stated needs and reworded data in the VOCT, a list of 20 customer requirements was formed. The team then created a list of 12 potential technical solutions intended to answer these needs. There was considerable difficulty associated with defining both requirements and features on a proper level of abstraction, but as most contacted parties were people with high levels of technical expertise, the solutions were ultimately presented on the level of singular features. These lists were used to create a survey, which asked for evaluations of importance, current satisfaction, expectation and perceived linkages as described in section 2.4.1. The level of abstraction for solutions was deemed too technical to understand by some interviewees with no background in machine development, but machine developing companies were able to return fully answered surveys and other users were still able to evaluate all other aspects aside from linkages. However, as the survey needed to be explained and could not simply be sent out as-is, a second round of interviews had to be conducted, where the statements from previous interviews were discussed in slightly more detail and the survey idea was presented.

Afterwards, additional time was required for completing the surveys. Due to the length of this process, only four fully answered surveys were received on time to be included in calculations in this study.

Development difficulties were evaluated on a scale of 1-9 by the current lead developer of the software, though the “A-2” and “Z-2” matrices could not be filled on time, so these were only rough estimates. The matrix formats were still saved for later use as an additional full-time developer was planned to be recruited, so more detailed definitions were left for that time. The market entry effect -factors were roughly estimated based on interviews and internal discussions.

Due to notable differences between companies within each initial segment and low number of survey respondents, evaluating segment-based adjustment factors was challenging, but some generalizations could be made based on comments concerning currently used methods, data availability and potential financial benefits. While creating generally applicable scaling factors was impossible at this stage, comparing estimates of the five competitive forces between each of the three segments allowed a qualitative, comparative assessment of factors relative between segments. A summary of this analysis is shown in Table 3.

Table 3 Market segment comparisons for BRAIN

	Manufacture only	Manufacture & upkeep	Other users
Rivalry among existing competitors	Somewhat low: solutions are commonly self-developed	Somewhat low: solutions are commonly self-developed	Higher: multiple commercial solutions are offered
Threat of new entrants	Medium: commercial solutions are being created	Slightly lower: solutions are being created, but likely not comprehensively for all needs	Higher: solutions are being created by both manufacturers and purely upkeep-focused companies.
Threat of substitutes	Medium: high level of technical requirements creates barriers	Medium: high data intensity creates barriers	Difficult to assess: new methods may be possible
Bargaining power of (data) suppliers	Medium: end users will require incentives to share data	Low: not much data is needed from completely external sources	Higher: manufacturers may not be willing to share design data
Bargaining power of buyers	Medium	Medium	Medium
Difficulty of entry	Medium	Lower	Higher
Profitability	Lower: not many valuable solutions can be offered	Medium: more solutions can be offered, though value still questionable	Higher: solutions can create great value if successfully implemented

As the factors could not be determined quantitatively, scoring was only performed on a case-by-case basis. Also, since data was not received from any companies in the other users –segment, this scoring cannot be applied if they are chosen as primary targets. Feature combinations and their profit and risk factors were not explicitly analyzed. However, two analysis solutions were found to have high value factors in all cases, so these were suggested for earliest development goals. Three other solutions formed a group of secondary priority targets, which could be used as next goals if better information is not obtained. Finally, two solutions had very widely varying evaluations depending on the customer, so these were suggested for consideration when initial target customers are decided. The HoQ matrix used in calculations is shown in an emptied state in Appendix 2.

A few general deductions could be made from the results of the study. Firstly, current tools are clearly lacking capabilities for fault diagnostics, so whenever issues arise, they must be analyzed manually. Finding the root causes of problems is heavily reliant on the professional expertise of maintenance personnel. As such, if technology is developed to support more automated diagnostics, this could certainly have value; however, many respondents were still skeptical about this possibility, as building comprehensive models for this purpose would require accounting for an extremely large amount and variety of data. Secondly, the most immediate value could be found in optimizing the quality of machines used for production, as vibration issues have a direct effect on product quality in these cases; oppositely, machines where vibrations do not directly affect quality, such as mining equipment, do not have many valuable needs to be solved. Thirdly, AMB solutions are targeted at many similar issues as the BRAIN technology, so AMB technology requires attention from multiple angles in the strategic planning of the BRAIN project.

Scenario data could still not be obtained at a detailed enough level for full analysis, which implies that a different initial approach would have been necessary for more precise results. However, some statements regarding future visions were collected, and their impacts concerning the BRAIN project were considered. A summary of this analysis is shown in Table 4.

Table 4 Scenarios for case BRAIN

Event	Probability	Impact for BRAIN
Active magnetic bearings become more common	Medium	As vibration-related issues are reduced through AMB, other alternative solutions may lose value. In this case, creating solutions that complement AMB would be more sustainable than competing with them.
Machine rotation speeds are continuously increased, causing old foundations to vibrate and break.	High (especially in paper production)	The effect of increased machine rotation speeds on foundations and related limiting values of operation become a valuable research case.
Sensors evolve and become less expensive	High	Cheap solutions could be offered for less critical machines, if large amounts of data from different sources can be processed effectively.
Energy production plants become smaller in scale	Medium	Small size, high efficiency generators and turbines become more valuable research targets compared to the currently dominant larger machines.
Data from different systems and sources is collected into cloud storage, allowing easier access when needed, where needed	Medium	Initial data access issues may solve themselves in many cases, so data transfer agreements and protocols may be more effective to set up at a later stage rather than at start (if possible, considering required early functions).

The final step of creating a roadmap is still too early to complete due to the business strategy being undecided, research and development team composition being partially undetermined and competitor analysis being incomplete, but some suggestions can be made based on the findings of the market study so far. The major deciding factor in determining the product development path is the choice of which concept to pursue. While the machine design support concept has less financial potential, it would likely allow much easier market entry. Creating design support tools primarily for the specifications of a few chosen manufacturers with service offerings would be easiest from a technical standpoint and would allow expanding into upkeep support through co-development over time. However, as initial value creation would be difficult, creating a sustainable business model may prove to be a challenge. On the other hand, creating an upkeep support directly for production companies would require significantly more effort and resources, so while the financial potential is much greater, this strategy would involve great risks and may not be possible to execute in the university environment.

Some points for consideration can also be suggested concerning the timing of developments. Firstly, as issues relating to machine supports and foundations have been noted as important in the context of lifetime performance and as a likely increasing future trend, the study of these and related solutions should be planned for an appropriate time depending on chosen strategy, specifically customer company priorities and upkeep concept development. Secondly, as AMB solutions are likely to impact the competitive environment in the near future, their potential should be further examined, and developments related to them should be considered for a slightly later point in time from the start. Thirdly, external data availability is likely to improve in the future, so they can likely be marked as obtainable resources after some time even if there is currently no clear way of accessing this data. As such, developing functions that are completely dependent on external data should be delayed to this point unless they are necessary high priorities, in which case separate data transfer agreements need to be negotiated.

4 CONCLUSIONS AND IMPLICATIONS

Innovation deployment will always face significant challenges, requiring more preparation and planning than often expected. Especially in the context of university innovations, much further development is typically required beyond concept creation before a new technology can be successfully transferred into the commercial environment. Yet, attempting to define the innovation deployment path purely through technical understanding has often led to failures, as there are numerous barriers to technology diffusion in industry that cannot be overcome simply by developing a technologically superior offering. There is certainly a need for a paradigm shift in the methodologies for commercializing innovations.

Studies have shown that including a customer perspective into product development planning processes can help significantly in creating a commercially attractive product, yet the methods that should be used for accomplishing this differ based on the type of innovation in question. More incremental processes should focus on creating value through building on core competencies, in which case reactive market research techniques are enough to steer developments in the best direction based on expressed needs and trends. However, for brand new, radical innovations, greater value can be found by exploring new perspectives through proactive research. By including customers in the creation process at an early stage and inviting them to find their own potential value-in-context, the deployment of the innovation can be defined in such a way that the value it can create for the customers is more apparent even at the earliest testing stages. Rather than creating solutions and then attempting to find a market for them, these methods allow solutions to be created based on knowledge of market needs, ideally resulting in more immediately attractive products. This should help overcome much of the resistance noted in the diffusion of innovations.

The importance of including a future perspective in market research has also often been noted. As development projects require long periods of time, the market environment can undergo significant changes before the planned products can be created. As such, it is highly suggested to always attempt to foresee significant trends and adjust plans accordingly to avoid the adverse effects of changes as well as to exploit new opportunities that arise from changes. Predicting the future is never easy and completely accurate predictions are impossible, but collecting future visions from multiple informed parties and conducting a scenario analysis can help with the long-term planning of a project. There are multiple methods to this, but they all typically require significant amounts of time, which can be a large issue with innovation deployment. If some type of scenario database idea can be implemented, this could be of help in the future; otherwise, it may be necessary to settle for more basic future descriptions.

The major challenge with the market pull approach is translating the voice of the customer into technical guidelines. The languages used in business and research contexts can differ greatly, resulting in confusion and mistaken assumptions. A commonly used methodology for aiding this translation is Quality Function Deployment, but in its base form, it may not be entirely suited for new innovation deployment, especially in the context of software and service innovations. Also, using the tools of QFD with only internal evaluations would miss the customer perspective and could lead to developments that seem logical to developers but do not have apparent value to customers. The modified approach suggested in this study should allow the inclusion of multiple perspectives into the analysis, theoretically leading to more comprehensive results that accurately depict the desirability of different planned functions. However, as it was not possible to fully apply the framework in the case study, this is still largely untested. More research would be required to fully validate the suggested framework, but some good results were obtained even from the more limited use case, so the suggestions seem to have merit.

The necessity of these customer-involved methods is especially apparent in university spinoff cases, where the failures of many commercialization projects can ultimately be attributed to lacking a market perspective in product development. University spinoffs have been noted to provide a better option for bringing innovations to the commercial scene compared to licensing, especially when developing general-purpose technologies, but there are numerous challenges associated with the spinoff creation process. However, many of these challenges should theoretically be possible to overcome by having deeper connections and cooperation between academics and industrial experts. The findings of this study imply that market research -based methods for defining innovation deployment should directly assist with overcoming some of the key difficulties in planning product development and commercialization, which, if this is proven to be widely applicable, has significant meaning for universities that are struggling to connect their research to commercial industries.

The studied case was a concrete example of the difficulty of opportunity recognition, where the actors possessed significant technological know-how, yet were not fully capable of defining how their technology could serve the market. Overcoming this challenge would require more information about the needs of commercial companies and the ability to synthesize scientific knowledge with an understanding of markets. The suggested process was designed to assist with this, and with it, some valuable results were certainly obtained. Yet, ultimately, not enough information was obtained on time to fully complete planning. The final definitions will heavily depend on a strategic choice, which can be supported by the obtained data, but lacking survey responses and missing organizational goals prevented the mathematical processing of the decision. In a larger scale study, more comprehensive results should be possible to obtain, but some decisions will always have to be made without complete information.

Ultimately, while methodological approaches can provide much needed information for supporting the act of defining innovation deployment, many evaluations will be subjective, and results cannot be taken as absolute facts. The suggested actions should help remove many uncertainties and allow for including multiple perspectives in planning, but in the end, success will depend on the expertise of decision makers as well as the commitment of all parties to following the defined path.

4.1 Applicability of the suggested framework

Full application of the suggested framework was not possible in the studied case due to limited time and lacking contacts. This may often be the case for university spinoffs, implying that a more simplified approach may be necessary in many situations. However, the extent to which the framework could be utilized still provided valuable information for the project, despite the results being partially incomplete, so the suggested approach seems to have merit. In projects with a larger scale and more experienced market researchers, the full utilization of the framework should be possible and this should provide highly valuable results. More testing would still be needed to fully validate these claims, however.

When it can be applied, the results of the suggested framework should prove useful for planning the deployment of the earliest testable product. However, further development beyond that stage will likely require a different approach. As adoption decisions become increasingly dependent on customer references, the five perceived attributes of innovations will no longer be a major factor. When development becomes more incremental in nature rather than radical, the effects of Kano quality distinctions on development priorities will change, possibly even becoming reversed. Finally, despite being based on defining deployment through observing the market, the framework is still feature-driven. As noted by Komssi et al. (2015), working with a feature-driven mindset causes multiple disadvantages, which hinder long-term planning. Specifically in the context of software development, Komssi et al. (2015) note three issues:

1. Low-level features do not provide a long-term perspective for solution development.
2. Low-level features are difficult to understand for non-technical persons, which limits cross-functional efforts and, thus, creativity.
3. The feature-driven mindset elicits only software-related requirements from customers, missing aspects of service and delivery.

These issues can be somewhat mitigated if the main HoQ of the framework is kept on a very high level of abstraction, but this increases the difficulty of evaluation and planning. As such, the suggested framework should only be used for early-stage planning on a relatively short-term timeframe.

The framework could potentially be applied in non-university environments as well, though this possibility requires more research. As university spinoffs are generally comparable to high-tech startups, this context seems most likely to benefit from the framework. The main requirements of utilizing the framework are a high level of technical expertise and the ability to obtain information from industrial experts, so if the involved actors are highly educated and able to show credibility, this should be possible.

One difficulty that was left unsolved is how to effectively include scenario analysis in the used models. Inputs for scenario analysis could likely be better obtained before introducing the technology concept, but controlling the direction for these conversations may prove difficult. Performing full scenario analysis will also require more time. This could be more viable for non-university innovation deployment projects, though setting up interviews may be more difficult compared to university projects. Universities also have some advantages related to acquiring technical knowledge, which is a basic requirement for technical feature definition and development difficulty evaluation. As such, while the framework could also be useful in the commercial environment, this will likely require additional time investments.

4.2 Suggestions for the BRAIN-project

Based on the results of the market research, an important strategic decision must be made before the earliest testable product can be completely defined. If the lower risk strategy of targeting manufacturers is chosen, the machine development support concept gains priority, as functions serving this purpose will have the highest effects on market entry. Further developments can then be made through co-development, though the team can be defined as a spinoff company with its own business goals. This necessitates the careful consideration of the business model definition. On the other hand, if the higher risk and reward strategy of targeting other users is chosen, the upkeep concept should define the offering to be developed. However, due to the greater resource requirement, the latter strategy may also require a deeper partnership, fusion or licensing agreement with an existing digital twin –focused company, where some currently incomplete assets can be quickly used to add value to existing products, and resources received in return can be used for the extended development process of an upkeep support product. This product could then be added to the existing portfolio, where it could create very significant value; however, separating the result into a spinoff business would likely not be possible, so from the specific viewpoint of university spinoff creation, this would not be ideal.

Before this decision is made, competitor analysis should be completed to more accurately determine the financial potential and possible business models for the different conceptual approaches. Once the strategy is decided, the roadmapping process should be completed to define the ultimate schedule and goals of the product development process. Meanwhile, some of the most generally applicable solutions can be developed further and market research can be continued to potentially obtain more information for strategic decision making. There is still a lot of work to be done, but the BRAIN-project certainly has potential for great results.

4.3 Topics for further study

Due to the limitations of this study, certain possible supplementary methods were not discussed, despite being identified as potentially useful additions to the framework. Further study of these methods could help improve the process. Namely, the Delphi Method could potentially give better results for both QFD and technology forecasting. This method, commonly cited as being introduced at the RAND Corporation around the 1950s, has often been used to facilitate discussions that elicit a broad range of expert responses around a particular topic and achieve some convergence in answers, leading to more accurate evaluations (Kauko & Palmroos 2014; Wakefield & Watson 2014). There is no single general definition of how the Delphi method should be conducted (Wakefield & Watson 2014), but in short, the traditional way is based on a multi-round survey, where statistics on previous answers are given out for each round while keeping all participants anonymous and each respondent is then allowed to modify their own answers and add comments (Kauko & Palmroos 2014). The method is commonly associated with forecasting, where Delphi studies can enable timelier information exchange compared to a literature search due to frequent lags in article and book writing and printing (Wakefield & Watson 2014). This approach could likely be used to enhance the accuracy of technology forecasting during the spinoff process, which could help with defining roadmaps. Additionally, as the suggested survey method for creating the HoQ is already based on compiling expert opinions and asking for re-evaluations, these results could theoretically be improved in accuracy by adding more rounds following the Delphi methodology. However, as answers are expected to be different between segments of interviewees, separate Delphi studies would likely be needed for each segment, which would require a great enough number of respondents for each segment. The time requirement for the study would also greatly increase with additional rounds. Due to the limited scope of this study, this methodology could not be tested in the studied case, but it could provide better information for larger projects.

The scoring-based decision-making process could also be better defined through the implementation of a multi-criteria decision making method such as AHP. The methods of AHP have commonly been combined with the tools of QFD in many different ways (Ho 2008), so integrating AHP into the suggested process could have potential for improving the results. One possibility would be utilizing AHP after potential feature combinations have been found to evaluate their attractiveness in relation to business goals and strategies, which would allow the quantitative inclusion of additional decision criteria from this perspective, simplifying the final decision making process. Another possibility would be to integrate AHP into the adjustment of importance ratings in place of the highly subjective measures of attributes affecting diffusion and development difficulties, enabling a more detailed analysis of value factors that could include more factors from the business perspective before scoring features. Either way, this approach would require the business goals of the development project to be more defined than in the studied case, so these methods could not be tested in this study.

Other methods for linking business strategy and organizational goals to the models could also be used to better define the results. Pai (2002) suggests that organizational goals should be defined and linked to SQFD by integrating aspects of Goal-Question-Metrics (GQM), stating that as user requirements and project goals can be exclusive, goals must be assessed and used in determining “proper” requirements. However, Pai (2002) notes that even their model lacks methods for actually identifying and evaluating project goals during the process, which is a significant and difficult step. This is likely even more difficult in the university spinoff context, where the organizational structure of the project team is not well defined and a managerial perspective cannot be easily distinguished. Komssi et al. (2015) also note the importance and difficulty of linking business strategy to roadmapping, specifically in the context of software product development. Their study noted a gap between strategic drivers and solution planning, such as the prioritization of features and customer segments, which typically causes a problem where urgent customer needs and short-term goals overrun and hinder long-term planning and the execution of previous plans. Komssi et al. (2015) suggest that the problem could be alleviated by allocating more time for solution planning from the strategic perspective and by having cross-functional workshop teams examine the business strategy and customer activities and then link the business potential of customer activities into the solution roadmap. However, these solutions are based on conditions in medium-size companies, and likely cannot be applied in the university spinoff context due to the small size of project teams, undefined business strategies and stricter time constraints. While the suggested framework is designed for relatively short-term planning, the integration of a strategic perspective is still clearly of importance. This challenge will require further study.

The framework also assumes that the required competencies for proceeding through the stages of spinoff creation can be developed or acquired. As Rasmussen et al. (2011) note, while there have been many studies on the university spinoff formation process, less attention has been given to exactly which competencies are necessary, who provides them, and how they are developed. The framework suggested in this study should contribute to developing an *opportunity refinement competency* by enabling a market-based approach for refining innovations into commercially viable products, but using it requires the ability to identify and interact with prospective customers and industry partners. According to Rasmussen et al. (2011), this requires a *leveraging competency*, which involves evolving credibility and entrepreneurial experience. A third competency identified by Rasmussen et al. (2011) is *a championing competency*, which requires different actors at different stages of spinoff creation; academic researchers may be important champions initially, but persons with a different background may be needed to champion the commercial aspects in later stages and mobilizing people in external organizations to champion project advancement can increase the likelihood of the spinoff reaching the credibility threshold. The main suggestions given by Rasmussen et al. (2011) for acquiring these competencies revolve around recruiting persons with industry experience into the spinoff team, yet the study does not define exactly what type of experience would be the most vital. As such, further study may be needed relating to which types of people would be the most efficient and capable of leading the spinoff process and the related market research. Utilizing and refining the suggested framework could likely be greatly improved by involving a larger team with more industrial experience.

Finally, the difficulties in including a scenario analysis in the suggested process imply that it may need to be performed as a separate study process, the results of which could then be accounted for in the main planning process. If the scenario database idea could be implemented and connected to roadmapping, this could likely allow for more dynamic planning, where development priorities could be periodically adjusted based on observations of future trends. However, as building such a model would require far more time and resources than typically available for spinoff projects, this may be unrealistic for singular cases. An interesting idea in this context could be for universities or related technology transfer offices to build and maintain a periodically updating general scenario database, which could then be searched to obtain information related to potential new ideas even before starting R&D projects. This idea could have potential for generally improving university spinoff performance in the future, but studying this idea would require a very different approach and viewpoint from this study.

5 SUMMARY

Defining a deployment path for a new technological innovation is a daunting task, which requires a significant amount of effort to be completed properly; however, it is a very necessary part of planning the development of a commercial offering. Especially in the context of university spinoffs, there exist numerous barriers that are nearly impossible to overcome without well-informed strategic plans. While it may be impossible to obtain full information for every decision, methods of market research and tools of analyzing obtained data can provide highly valuable insights for strategic decision making.

The main suggestions for the research issue of deciding the first product deployment path while market signals are weak are the deeper involvement of potential customers into the planning process and the linking of market needs with technical ideas through applied QFD methods combined with frameworks for analyzing present markets and future directions. The barriers to the diffusion of innovations are rarely intuitively understood, but the suggested methods should naturally direct researchers and developers towards finding solutions that are not only technologically more advanced than current offerings, but also more well-suited for the industrial use context and capable of demonstrably creating great value. This approach should also solve the research question of which factors should be considered when presenting a new technology, as the innovativeness of the contacted individuals and companies as well as the product factors affecting diffusion considered in this process should theoretically have the most impact on the chances of success of the innovation deployment project. The inclusion of foresight in product development planning should also greatly improve the chances of these types of projects achieving sustainable business operations in the long term.

The QFD-based approach should by definition be a very useful tool when attempting to overcome the juncture of opportunity recognition, which involves matching unfulfilled market needs with new solutions. The scoring methods of QFD should help with the research issue of assessing the market potential for different conceptual solutions. This has been noted as one of the first major challenges in university spinoff creation, implying that applying the suggested process should be done during the earliest phase of a spinoff project. University spinoffs are also relatable to general high-tech startups in many ways, so the same framework could likely be applied to such cases as well.

In the end, fully defining the earliest testable product was not possible in the studied case despite this being the goal that the framework was designed for. Succeeding in this task would have required more time, a greater number of experienced participants, and more defined organizational goals. Two concepts for a software product with some specifications and multiple potential customers for each were found, but the final definition will depend on strategic choices, which cannot be made before the business goals and initial target markets of the project are decided. This illustrates that the spinoff creation process is not as linear as often depicted. In this case, the juncture of entrepreneurial commitment must be overcome before opportunity refinement can be finalized. While the suggestions of this study do not provide solutions for this challenge, the achieved results should create a strong basis for advancing product development as the project moves forward. The future of the project will now depend on the skills and commitment of the people behind this great technological innovation.

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APPENDICES

Appendix 1. Voice of the Customer Table (VOCT) adapted from ReVelle et al. (1998), replacing function and task columns with Kano quality

			Application context											
Code no.	Demographic	Voice of customer (Verbatims)	Who uses it?	What is it used for?	When is it used?	Where is it used?	Why is it used?	How is it used?	Reworded data	Demanded quality	Quality characteristics	Reliability (Failure Mode)	Kano quality	Comments
1														
2														
3														
4														
5														
6														

Appendix 2. The HoQ matrix base used in the case study