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PSS Support for Maritime Technology Ventures: From Exploration to Methodology and Theory

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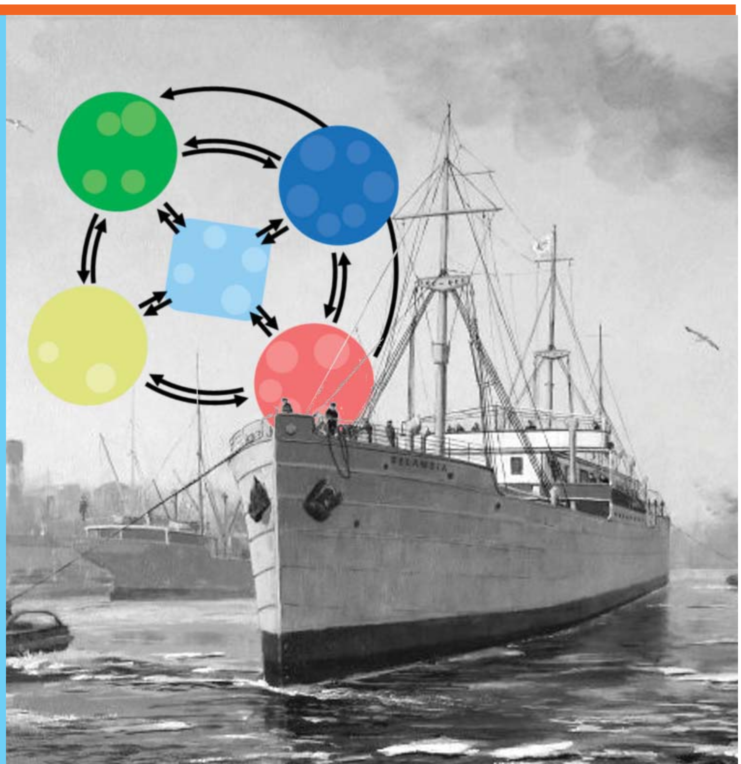
PhD Thesis



Jakob Bejbro Andersen

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PSS SUPPORT FOR MARITIME TECHNOLOGY VENTURES

FROM EXPLORATION TO METHODOLOGY AND THEORY

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PhD thesis
Jakob Bejbro Andersen 2015

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Cover picture: M/S Selandia – painting by Johannes E. Møller, used with permission from MAN Diesel & Turbo, Niels Søholt)

EXECUTIVE SUMMARY

In the last decade, the situation for Danish maritime suppliers has gone from growth and prosperity to crisis and foreclosures. The reason for this downturn can be found in macroscopic factors like the economic crisis of 2008, the closing of Danish shipyards and the emergence of cost-efficient, competitive Eastern suppliers.

The Danish suppliers - by some considered the world leaders in terms of technological knowledge - are faced with a difficult choice: Either try to survive by cutting costs and competing on price or attempt to leverage their unique knowledge of technology to the market and build new business ventures, which are not dependent on cost as a competitive factor. The recommendation of this thesis is to pursue the latter option and adopt entrepreneurial strategies as a means to future prosperity. To achieve this goal, the area of Product/Service-Systems (PSS) is introduced as a candidate for a supporting framework. PSS holds the potential to enable the maritime suppliers to build innovative businesses based on a superior understanding of the customers' operational activities and a portfolio of PSS offerings tailored to address the needs related to these activities.

Before the appropriateness of PSS support can be established, the phenomenon of technology entrepreneurship processes has to be understood. To build this understanding, the research areas dealing with the phenomenon are explored and an empirical study is conducted. The exploration of the entrepreneurship and engineering design fields reveals that the phenomenon of technology entrepreneurship processes is under-researched and that few empirical insights exist. A lack of appropriate research methods for researching the phenomenon is identified as a root cause for the poor empirical understanding. To build an empirical understanding, the thesis proceeds to develop a new process research tool and a related Entrepreneurship Process Research (EPR) methodology. The software-based, automated research tool is then used to gather empirical data from a large number of technology venture processes and to build an extensive and detailed process dataset.

On analysing the empirical data, three studies lead to a number of findings: The first study reveals that technological dimensions affect the process characteristics, mandating special attention be given to technology-dependent ventures. In the second study, an attempt is made to validate an existing theory for entrepreneurship process against the data. This study fails to find proof for or against the assertions of the theory. In the last study, a grounded theory approach is used for building a conceptual framework for entrepreneurship processes. As such, the framework is entirely abduced from empirical evidence. Its explanatory power is tested by applying it to a number of maritime cases.

Based on the empirical understanding of the phenomenon, the thesis proceeds to discuss the conceptual likenesses between the entrepreneurial process and a traditional engineering design process, plus the similarities between the entrepreneur and the designer. In extension of this, the relevance of a number of PSS tools as support for the processes observed is discussed. Great potential is found for the use of PSS and its tools in supporting technology entrepreneurship processes. Furthermore, the new context is found to pose a challenge to the tools, which need to be adapted and given new roles in order to support technology venturing.

In closing the thesis, the potential for research and practice synergies at the overlap between PSS, technology and entrepreneurship processes is discussed and a number of promising venues for future efforts are proposed.

To Katrine, for her unwavering support and precious ability to inspire calm in trying times.

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First and foremost, I would like to thank my supervisor Tim McAloone for supporting me in pursuing academic opportunities and notions, which were sometimes off the beaten track. Without Tim's inputs, flexibility and willingness to explore I am not sure a PhD would have been a viable career path for me.

I am also very grateful to Thomas J. Howard for our ongoing discussions and for our collaboration on the Innovation & Product Development course, which has been crucial to the results of my studies. As with Tim, Tom has been willing to accompany and support me on many academic excursions.

Several other colleagues have been kind enough set aside time for discussing my research and providing feedback. Jamie O'Hare, Martin Ravn, Louise Laumann Kjær, Aris Pagoropoulos and Phil Cash have all provided important help at various times of my studies and I thank you for it.

I would also like to extend my thanks to my benefactors. This PhD thesis has been co-financed by the Danish Maritime Foundation and the Technical University of Denmark. The thesis also had close ties to the PROTEUS innovation consortium, which was financed by the Danish Agency for Science, Technology and Innovation, and supported by ten companies from the Danish maritime branch.

During the PhD, a number of applications have been sent to secure financial support for the research tool (the so-called "development log") developed as part of my studies. The Danish Industry Foundation and the Young Enterprise Denmark foundation both chose to support the tool's development. The tool has been a central element in supporting the conclusions of the thesis and I thank the two foundations for enabling its creation.

Finally, I would like to thank the four rounds of students I have taught in the Innovation and Product Development course. Without their inspiring entrepreneurial work and willingness to endure early versions of the tool, I would not have been able to build an empirical dataset of the same quality.

- A big thanks to all of you!

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GLOSSARY OF TERMS

Term	**Meaning**
AI	Artificial Intelligence
Bias (sampling, researcher)	See section 1.3.4
DBSCAN	Density-Based Spatial Clustering of Applications with Noise
Entrepreneur	A person who seeks to exploit new opportunities by using new means-end relationships
Entrepreneurship	What the entrepreneur engages in
Environment	The setting / ecosystem of the entrepreneurial effort
EPR Methodology	Entrepreneurship Process Research Methodology
EPR tool	Entrepreneurship Process Research tool
Generalisability (internal, external)	See section 1.3.4
I	Individual entrepreneur or team of entrepreneurs.
ML	Machine Learning
New means-end relationships	Exploiting a new opportunity by assembling and leveraging new stakeholders, technologies and business models.
NLP	Natural Language Processing
Opportunity	A potential for capturing value
PSS	Product/Service-Systems
R&D3	Research & Development Degree of Difficulty
Reactive effects	Epistemological challenge relating to the researchers' effect on the observed phenomenon.
Reliability	See section 1.3.4
The Development log	Same as *EPR tool*
TNV	Technology Need Value
TRL	Technology Readiness Level
Validity (descriptive, interpretive, theory)	See section 1.3.4
Vectorisation	Changing sentences of words into binary vector format

CHAPTER 1:
INTRODUCTION TO RESEARCH AREA AND THESIS

What should a company do if its local value chain disappears and it has to compete on a global market with competitors providing much cheaper products of similar quality? This question has been on the minds of managers in the Danish maritime branch for more than a decade. Despite showing some positive indications, the Danish maritime branch is far from returning to the prosperity and growth of its golden age in the 20th century.

The branch currently has two vital assets that could potentially offset the cost advantage of its Eastern competitors: Its world-leading knowledge of maritime technology and -operations and its geographical placement, right next to most of the customers – the shipowners.

The proposition of this thesis is that the suppliers of maritime technology solutions need to leverage their deep technological insight and favourable locality to create innovative and disruptive businesses. To do this, the companies need to adopt entrepreneurial strategies.

The objective of the thesis is to take the first crucial step towards helping these companies to execute such strategies, by helping to understand the entrepreneurial processes by which advanced technology is developed into new, disruptive businesses.

1.1 THESIS STRUCTURE AND RESEARCH QUESTIONS

The thesis is structured to reflect the components of the study that has been conducted. In Figure 1, the narrative of the thesis is visually represented. The different parts of the figure are directly related to the chapters in the thesis. Each chapter will be introduced below.

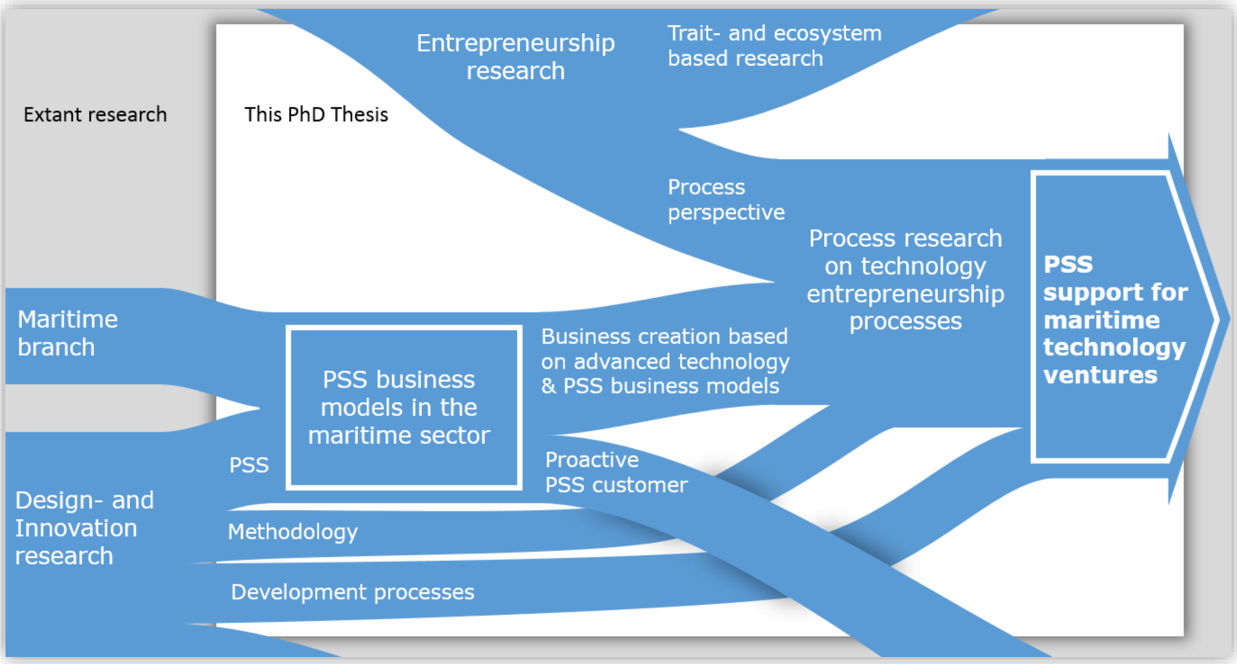


Figure 1: The narrative of the PhD thesis [own]

1.1.1 CHAPTER 2: FRAMING THE RESEARCH

The starting points for the thesis are the research questions:

> ***RQ1.1:*** *What are the current challenges of Danish maritime suppliers?*
>
> ***RQ1.2:*** *What options do the suppliers have with regard to addressing its challenges?*

To answer these questions, the first chapter describes the context for the study, by introducing the maritime branch along with its history. Based on this, chapter 2 then describes the motivation behind- and contents of the PROTEUS consortium, which was established to address the needs of Danish maritime suppliers (more on PROTEUS in section 2.3, page 17). The empirical results from an initial exploratory study of the branch are then presented. In discussing these results, two diverging paths for further research are identified – each representing a tentative response to RQ1.2:

> ***1st potential research path****: Exploring the customers' view on Product/Service-System solutions.*
>
> ***2nd potential research path:*** *Seeking an understanding of entrepreneurial processes dealing with advanced technology.*

A discussion in terms of Ph.d. objectives and potential effect determines that the 2nd path is the most appropriate to pursue. This research path forms the basis for the remaining chapters of the thesis.

In extension of the discussions regarding the value and potential of PSS, the following hypothesis is also formulated:

> ***H1:*** *Entrepreneurial processes dealing with advanced technology can benefit from the tools and methods found in design- and innovation research in general and PSS in particular.*

1.1.2 CHAPTER 3: ENTREPRENEURSHIP PROCESSES AND ADVANCED TECHNOLOGY

To investigate entrepreneurship processes and the role of advanced technology, the following questions are asked:

> ***RQ2.1:*** *What type of support does the tech venture require to succeed with entrepreneurial strategies?*
>
> ***RQ2.2:*** *Can entrepreneurship research provide the necessary (process) support?*

In this theoretical chapter, the background for understanding entrepreneurial processes dealing with advanced technology is studied. This study reveals that the field of entrepreneurship is highly focused on understanding the traits of the entrepreneur and the environment in which entrepreneurs operate. The subject of entrepreneurship *processes* has received little attention and the few existing studies are empirically weak. There is need for research methodologies that allow for collection of empirical data from entrepreneurship processes.
Furthermore, the entrepreneurship research field is found to be focused on ventures dealing with simple, off-the-shelf technology. The role of advanced technology and its development is not covered to any great degree.

The findings from RQ2.1 and RQ2.2 form the basis for the next research questions:

> ***RQ2.3:*** *How can entrepreneurship research be strengthened to better cater to the needs of technology venture processes?*

To address this need for research tools and to understand the role of technology, the area of design- and innovation research is introduced. Scholars in this area have been researching design processes for decades and they have an intimate knowledge of technology and its role in commercial success.
It is concluded that the area of entrepreneurship process research can potentially benefit from the tools and concepts of design- and innovation research. This insight is the background for the final research question:

> ***RQ3.1:*** *How can PSS and other design- and innovation research areas be used to support venture- and technology development processes?*

1.1.3 CHAPTER 4: THE REQUIREMENTS FOR ENTREPRENEURSHIP PROCESS RESEARCH TOOLS

To strengthen technology venture process research (RQ2.3), appropriate research tools are needed for collecting and analysing process data. In this chapter, a number of practice-related requirements are formulated for research tools dealing with entrepreneurship processes. These requirements are derived from extant knowledge of entrepreneurship processes and an auto-ethnographic study of a high tech venture in the maritime sector. Alongside the practice-related requirements, a set of requirements relating to research rigour are formulated based on literature concerning qualitative and quantitative research methodology.

A number of process research tools are then listed and evaluated in terms of the requirements set forth. Although many tools comply with a subset of the requirements, none are found to be in full compliance with the practice-oriented and research rigour related requirements. On this basis, it is concluded that a new tool is needed for researching entrepreneurship process

1.1.4 CHAPTER 5: A NEW RESEARCH TOOL FOR ENTREPRENEURSHIP PROCESSES

This chapter describes the development of a new research methodology and related research tool for researching the processes of entrepreneurs. The methodology proposed involves an end-to-end system for capturing data, testing hypotheses and deriving meaning from a process. The methodology is evaluated against the research tool's requirements, revealing strong compliance on all points. In addition, examples are provided of datasets created using the new research tool.

1.1.5 CHAPTER 6: EMPIRICALLY TESTING AND BUILDING PROCESS THEORY

In this chapter, the methodology developed is tested in three use scenarios, based on different theoretical outsets:

- **Study 1: Understanding the sample and structured analysis of data**
  In this study, the basic structure of data captured using the tool is analysed from various perspectives, yielding a number of insights on process characteristics and their relation to various contextual parameters.

- **Study 2: Testing heuristics on process data**
  This study will use Effectuation theory, which has a set of pre-defined heuristics, which can be directly tracked in the data gathered from the process.

- **Study 3: Building theory from process data**
  In this study, machine learning algorithms are used to identify patterns of interest in the process dataset. These patterns are then used as building blocks for process theories and form a *conceptual framework* for technology entrepreneurship processes.

Each study is used as a basis for discussing the usefulness and quality of the methodology.

1.1.6 CHAPTER 7: PSS, DESIGN- & INNOVATION RESEARCH AND ENTREPRENEURSHIP

In this chapter, the empirical findings and central concepts in entrepreneurship research are used as a basis for discussing the relevance of design- and innovation research and practice in supporting entrepreneurial processes. In particular, PSS research and a number of tools related to that area are identified as promising candidates and discussed in terms of the newly established *conceptual framework.*

In closing the chapter, the potential for new research at the intersection between design- & innovation research and entrepreneurship is pointed out.

1.1.7 CHAPTER 8: THESIS CONCLUSIONS AND PERSPECTIVES

In this last chapter, the conclusions of the thesis are stated and related directly to the research questions and hypothesis phrased in the early chapters. Also, the limitations of the conclusions are treated.
Finally, a number of prospective venues for future research are proposed as continuations of the contributions and findings of this thesis.

Figure 2 shows which chapters provide answers to research questions and how they relate to the overall narrative of the thesis.

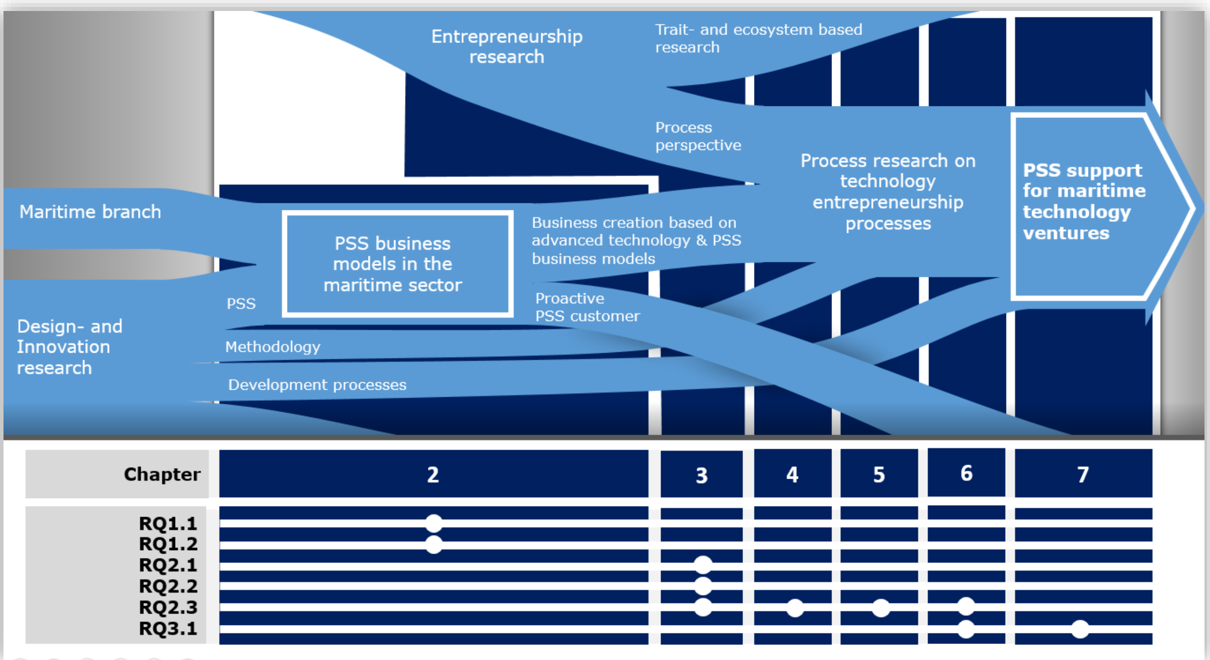


Figure 2: The chapters and research questions in relation to the thesis narrative [own]

1.2 BUILDING ON PROTEUS

The thesis builds on insights from the PROTEUS (PROduct/service-system Tools for Ensuring User-oriented Service) innovation consortium, which was established in 2010 as a collaboration between the Technical University of Denmark, Copenhagen Business School, the maritime suppliers' branch association Danish Maritime and ten maritime supplier companies from Denmark. The PhD has not formally been a part of the consortium, but the empirical data from the consortium has been used to frame and focus the research – as described in chapter 2. Read more about PROTEUS in section 2.3, (page 17).

1.3 GENERAL RESEARCH METHODOLOGY

This section describes the general research methodology used for the PhD study. In addition to this, each chapter of the thesis is initiated with a section providing further details on chapter's research design.

The overarching framework for the thesis has been adopted from Robson's book *Real World Research* [Robson 2011] and its guidelines for conducting rigorous research in real world settings. Additionally, the methodological approaches of Miles and Huberman [Miles 1994] have also contributed greatly to the application of and reflection on methodology described herein.

1.3.1 RESEARCH PHILOSOPHY

The present thesis is written based on a *critical realist* philosophy of science [Robson 2011; Huberman & Miles 2002]. This perspective dismisses the notion of an objective truth found in *positivism* and asserts that reality can be studied not only through physical phenomena, but also through abstract phenomena like human opinions, meanings etc. As such, the phenomenon being studied is construed by the subjective views of the participants. Also, different realities for the same phenomenon can co-exist as they relate to the views of different groups or persons.

In pure realism, the scholar assumes that the phenomenon exists irrespective of the researcher's presence and that it can be *known*. This view is opposed by *relativism*, where the phenomenon is construed as much by the researcher as the participants. In *critical realism,* a compromise between the two is found where the *phenomenon* is indeed affected by the researcher, but where due criticism and reflection of the researcher influence is can account for any *reactive* effects (bias) and reveal the unaffected nature of the phenomenon.

1.3.2 RESEARCH PURPOSE AND -QUESTIONS

Robson recommends forming research questions based on an overarching research purpose and, if necessary, revising or adding to these questions as the study unfolds and new purposes emerge. Section 1.1 indicates that in the current project, the formulated research questions have been refined over time, as the specific purpose of the research was elucidated. Following Robson's guidelines for formulating research questions [Robson 2011], each question was formed based on the underlying purpose, as shown in Table 1.

#	***Purpose***		***#***	***Research question***
1	Understand the maritime branch, the challenges it is facing and the possible solutions to these.	>	**1.1**	What are the current challenges of Danish maritime suppliers?
			1.2	What options do the suppliers have with regard to addressing its challenges?
2	Understand the processes of technology venture creation in startups and spinouts	>	**2.1**	What type of support does the tech venture require to succeed with entrepreneurial strategies?
			2.2	Can entrepreneurship research provide the necessary (process) support?
			2.3	How can entrepreneurship research be strengthened to better cater to the needs of technology venture processes?
3	Help Danish maritime suppliers address their current challenges	>	**3.1**	How can PSS and other design- and innovation research areas be used for supporting venture- and technology development processes?

Table 1: Formulation of research questions

1.3.3 DECIDING ON A RESEARCH DESIGN STRATEGY

The research question itself can be used as a starting point for deciding on a general research design. In Robson's definition, the *research design strategies* can be *fixed, flexible* or a combination of the two, *mixed*. Fixed designs imply that a pre-specification of the phenomenon is possible and that research can be conducted based on this. Conversely, flexible designs evolve over time as the study unfolds. In mixed designs, the research design strategy can change over time – for instance starting with an explorative, flexible design and then transitioning into a fixed design.

According to Robson, if the research question calls for magnitudes and quantification (e.g. "*How many...*"), the fixed design strategy is the most appropriate. Such designs are useful in research contexts where large amounts of data are to be gathered and processed in a coherent and *quantitative* manner.

If a research question is of a *"what's going on"* type, the pre-specification of the phenomenon is unavailable and the feasible research strategy is a flexible design. The research questions presented above can all be said to fall into the latter category. This can be seen as an indication that the study is dealing with an area about which little is known.

Three widely used research strategies [Miles 1994; Robson 2011], which are also used in several instances in this thesis, are:

> *Case study:* Here, a chosen case is explored using a range of data gathering methods, which are often chosen as the study unfolds. Methods include surveys, documentary data, interviews etc. Case studies were used intensively in the initial stages of PROTEUS and they provide a substantial part of the basis for chapter 2 in this thesis, where an overview of the branch is established. This overview was created through multiple interviews with companies in the consortium, workshops, reading of annual reports and other accessible documents.
>
> *Ethnographic study:* In the ethnographic study, the researcher immerses him- or herself in the context being studied for an extended period, in order to understand the characteristics of the group being followed and its activities. The observer (researcher) can participate to varying degrees, ranging from the *complete participant*, where he or she is participating fully and on the same terms as the rest of the group, which is unaware of the research being carried out, to the *observer-as-participant*, where the researcher follows and observes the group, but does not interact. In between the two extremes, the *participant as observer* role is found, where the researcher participates fully and the group is aware of the research agenda [Robson 2011; Nambisan & Baron 2009]. In exploring the maritime branch and its stakeholders, this approach has been adopted as a means to study the internal workings of a shipowner, named TORM (chapter 2). Another flavour of ethnographic studies is auto-ethnography [Hayano 1982; Miles & Huberman 1994], where the researcher and his/her activities are the focus of the study. In chapter 3, an auto-ethnographic study is used as a basis for understanding a technology entrepreneurship process.
>
> *Grounded theory:* This approach is less of a data capturing strategy and more of a sense making and theory building strategy. In grounded theory, corpuses of qualitative data – such as transcribed interviews - are divided into sub-elements and grouped into clusters of similar topics or other features [Glaser & Strauss 1967; Charmaz 2006]. In this thesis, grounded theory is used in chapter 4, as a basis for creating an exhaustive tagging system for the research tool being developed. In chapter 5, an automated variety of grounded theory, called *data clustering*, is used for identifying heuristics in process datasets.

1.3.4 RESEARCH RIGOUR ON APPLIED AND REFLEXIVE LEVELS

This thesis employs research methodology at two levels of abstraction: On an *applied* level, where research methods are being used for reaching various outcomes (e.g. providing an empirical basis for understanding a phenomenon) and on a *reflexive* level, where the research methodology itself is the subject of discussions and analyses.

The *trustworthiness* of research methods [Robson 2011] and their results is an important consideration on both the applied and reflexive level. The following areas are relevant in assessing the trustworthiness of research methods and they will be used as indicators throughout this thesis:

Description validity: Does the data captured actually hold enough detail / correct elements to describe the desired phenomenon? [Maxwell 2012; Gero & McNeill 1998]

Interpretation validity: Interpreting data based on a framework that is given beforehand rather than letting the data reveal the correct interpretation [Maxwell 2012; Miles & Huberman 1984]

Theory validity: Considering only one theoretical explanation of the observed phenomena and not exploring alternative theories. [Maxwell 2012]

Triangulation: The use of more than one data source or using different methods or theories for reaching the same conclusion greatly improves the confidence level of the conclusion. [Malterud 2001; Robson 2011]

Sampling bias: Traditionally a staple of quantitative research, the notion of sampling bias relates to the fact that a sample can be a poor representative a general population. This factor is important when trying to draw conclusions for an entire population based on a limited number of samples. In real world research, various factors are also likely to change the characteristics of a sample over time. Non-respondents are also a source of bias. [Robson 2011; Malterud 2001]

Researcher bias: Researchers (often unknowingly) approach a given empirical research task with a set of predispositions and expectations that can bias the interpretation of the data gathered. [Malterud 2001]

Reliability: How reliable is the “instrument” for gathering and analysing data? If the researcher him-/herself is the instrument, measures should be put in place to ensure consistent data capture and interpretations. [Robson 2011]

Internal generalisability: Even within e.g. a case study, there is a risk that the conclusions drawn are specific to the respondents that have been interviewed. [Maxwell 2012]

External generalisability: For research involving human actors and systems, it is exceedingly difficult to generalise to other subjects or groups. This can be mitigated by removing contextual factors in very large, random datasets or by precisely validating the mechanisms necessary for understanding not only the present sample, but other samples as well.[Maxwell 2012]

The above indicators can be affected by the general characteristics of a given research method (e.g. a certain data capture method can be particularly reliable) as well as the instantiation of the method in a research project (e.g. how well did the researchers conduct their survey?). When dealing with *applied research methodology*, both contributing factors will be evaluated in terms of the indicators. When dealing with methodologies on the *reflexive level* the main concern will be evaluating the general characteristics of the method or strategy.

Having introduced the research area and purpose; the research questions and hypothesis; and the general research methodology applied in the thesis, the next chapter will address the main research object for the thesis: The maritime branch and its challenges.

CHAPTER 2:
UNDERSTANDING THE MARITIME BRANCH AND ITS CHALLENGES

RQ1.1:
What are the current challenges of Danish maritime suppliers?

RQ1.2:
What options do the suppliers have with regard to addressing its challenges?

In this chapter, the framing of the thesis is described. The context for the project, the Danish maritime branch is introduced along with the PROTEUS consortium, of which the PhD is a part. The PROTEUS consortium is based on the theoretical area called Product/Service-Systems (PSS). Using PSS as a theoretical framework for understanding the present situation in the branch, challenges and opportunities for new research paths are discussed. Based on a discussion of these paths in terms of the objectives of the research project, one path is chosen to form the basis for the thesis.

2.1 CHAPTER RESEARCH DESIGN

For the historical sections, which describe the Danish maritime industry and its origins, historical accounts have been studied, stemming from research and from companies in the branch. The descriptions of the current situation in the maritime branch are based on the extensive case-study work done in the context of PROTEUS (see section 2.3) and in the time after the conclusion of the innovation consortium. The empirical studies in PROTEUS included several hundred hours of interviews of stakeholders in supplier organisations, as well as in other organisations such as shipowners and branch interest organisations for shipowners and suppliers respectively. Interviews were taped and central parts transcribed and shared with interviewees for validation. By interviewing employees in different parts of each organisation, the likelihood of internal generalisability was increased. As the studies followed a fixed design strategy, the concern was on getting *purposive* result [Robson 2011], rather than reproducible one where *external validity* can be argued.

The second part of the chapter, which describes Product/Service-Systems (PSS) and their potential value to the maritime branch, is based on an extensive study of extant research literature on the topic. To strengthen the discourse, and to enable more cross-disciplinary utility of the results, the PSS literature study was complemented with a study of literature in integrated solutions literature, which treats many of the topics found in PSS research.

The third part of the chapter also draws upon the empirical foundation created in PROTEUS and also introduces the results of a series of structured interviews aimed at uncovering the present state of the suppliers' offerings and the degree to which PSS solutions were already used.

To understand the customers' perspective on PSS, the chapter proceeds to describe a study conducted after the conclusion of PROTEUS, which focused on the shipowner TORM A/S. This ethnographic study was conducted over a 24-month period with the researchers in a *participant as observer role* (see section 1.3.3).

To the extent possible, the general validity of the empirical findings has been strengthened using triangulation [Malterud 2001] based on alternative methods.

2.2 THE DANISH MARITIME BRANCH

To understand the starting point for this research project, one has to understand the origins and current situation of the Danish maritime branch. The purpose of the following sections is to establish this understanding.

2.2.1 A SEAFARING NATION

Denmark has always been a seafaring nation – partly due to its island geography and its strategically favourable position at the portal to the Baltic Sea. Today, "Blue Denmark", as defined by companies working within Offshore Oil and Gas; Maritime Equipment; Ship Building; Shipping and Consultants/Service Companies, is responsible for around 10% of the Danish GDP [Arbejdernes Erhvervsråd 2014]. The main contributors to this economic activity are the Danish shipowners, who are responsible for transporting around 10% of the world's goods measured by value. Considering that the Danish population only constitutes around 0,075% of the world's population, it is clear that the maritime branch has a strong influence and role in Danish commerce and society.

2.2.2 BECOMING A SHIP BUILDING NATION

According to McGouldrick, whose account of the origins of Danish shipbuilding forms the basis for the coming sections [McGouldrick 1953], Danish shipowners have been a large part of international shipping for centuries. However, until the late 19th century, most vessels were commissioned abroad – often in Britain, due to the country's deep knowledge of steel ship production. However, in a spot of opportunism, the actions of a Danish company would change this trend. The manufacturing company Baumgarten & Burmeister (founded 1846) was based in Christianshavn on the canals of the Danish capital Copenhagen [Møller et al. 1998]. The company produced steam engines and other steel components, but did not have any experience with shipbuilding. However, in the 1850s when the Danish navy put out a call for 11 steel ships for troop transport, the company was successful in winning the contract. From this point, the shipyard continued a limited production of vessels until 1865, when the partner Baumgarten, chose to retire. At this time, a new partner entered into the company – an Englishman and former director of the naval dockyards named William Wain. Wain was an accomplished ship builder, with many innovative ideas within improved propeller design, steam engine improvements and floating docks. Wain's inclusion in what became Burmeister & Wain (B&W), sparked a 10-year period of unprecedented growth for the company, which had to drastically expand its capacity with a nearby dock in Copenhagen's Refshaleø.

The success of B&W spurred on the initiatives of other stakeholders, meaning that more shipyards were appearing in other parts of Denmark. Despite the rise of the Danish ship building industry, these yards produced only small vessels, appropriate for domestic operation. To support the production of ships, competent workers and engineers from Belgium, France and Britain had to be imported. However, as the shipbuilding industry got a foothold in Denmark, so did the national knowledge base and training programmes within maritime technology. At the turn of the 20th century, the shipyards could rely almost entirely on Danish engineers and workers.

2.2.3 TECHNOLOGY INNOVATION AND THE BEGINNING OF MODERN SHIP BUILDING

Although succeeding in importing technological knowledge and competencies (e.g. on steel ships) from abroad, the Danish shipyards were not initially the innovators of the industry. This would change dramatically in 1912, where B&W could announce a game-changing innovation.

The diesel engine was gaining in popularity at the turn of the 20th century and several shipbuilding companies were looking to license the diesel technology from Rudolph Diesel, the inventor. B&W were successful in getting this license, which initially was not particularly attractive due to a restriction stipulating that it could only be used for sales in Denmark. After several years of heavy investment and internal development at B&W, the value of the license was becoming limited, as the design described in the license was uneconomic. Instead, a number of in-house innovations [Rosén 1966], which had emerged in the testing if diesel engines in the facility and aboard vessels, meant that B&W had now become the technology leaders in maritime diesel propulsion. The internal development at B&W had enabled them to more than double the power output of the engine and allow for reverse operation – both of which were crucial features for ship operation. After eight years of development (1904-1912), the company was able to present the world's first diesel ship, the M/S Selandia.

CASE EXAMPLE: THE M/S SELANDIA

Compared to steam-engine based vessels of the time, the Selandia had a longer range, larger capacity (around 10%) [Rosén 1966; Reuß 2012] *and needed a crew of only 8 - compared to the 25 seamen needed on a steamer. In other words, the Selandia was what one today would call a disruptive innovation in shipping.*

Figure 3: M/S Selandia in Bangkok, 1912 [author unknown, work in public domain]

The unique vessel soon gained international notoriety and was inspected by, among others, Kaiser Wilhelm the 2^{nd} and Sir Winston Churchill. In the following years, the order books were filled at B&W and a new era of ship building in Denmark was sparked. Along with a significant expansion of B&W in Denmark and in subsidiaries in the UK, 11 other large shipyards were founded [Møller et al. 1998]. Along with B&W, four of these new entrants - Aalborg, Nakskov, Odense and Frederikshavn - survived the two world wars and subsequent economic depression to become the backbone of Danish shipbuilding.

The new-build activity at the Danish shipyards became the end of a vast value chain of Danish suppliers specialising in a wide variety of maritime technologies, such as boilers, hull coatings, safety equipment, flue gas cleaning and pumps. Since its emergence, the branch has become well known for its high quality components and strong technological and operational knowledge.

2.2.4 RECESSION IN THE DANISH MARITIME BRANCH

Following the many years of successful utilisation of the shipyards as a channel for selling components and services, the economic deroute of the Danish shipyards, culminating with the closing of the Odense yard in 2012 was a major setback for the branch. The fact that the

Danes could build the best ships and produce the best components was no longer enough. They also had to be competitive on price. Despite its status as one of the most technically advanced yards in the world, using robots for large parts of the ship building process in order to save costs, the Odense yard never managed to compete with its far Eastern competitors. Orders were being placed in Korea, Japan and China, not Europe, where Asian suppliers were catching up on technology knowhow while at the same time maintaining low costs. In Korea, heavy government subsidies for shipyards further increased their competitive edge.

In the early 2000s, the far Eastern yards were in such a high demand that order books were filled years into the future and low cost, low quality vessels were being launched at unprecedented rates. This assembly line was optimised to a degree, where the customer was no longer given the option of choosing components on the vessel. Rather, only one vessel type was on offer and the line of customers waiting to buy was too long to accommodate special requests. Consequently, there were examples of vessels being produced and subsequently modified elsewhere, to better suit the needs of the shipowner. The Danish maritime suppliers, who were struggling in the wake of of Danish shipyards closing down, found it exceedingly difficult to sell their products to the far Eastern shipyards, who were using a pre-defined set-up of low-cost sub-suppliers, defined in a so-called makers list.
At the height of the industry’s activities in 2003, 77.500 people were employed in the maritime branch in Denmark. With the closing of the large ship yards and geographical changes in new build activity, this number was reduced to 63.000 people in 2013 - a drop of 19% [Arbejdernes Erhvervsråd 2014].

2.2.5 THE FINANCIAL CRISIS AND THE SHIFT TOWARDS OPERATIONS SUPPORT

The order books of the shipyards were full at the time of the financial crisis in 2008. As the time it takes from the contract for a new vessel is signed until it is delivered is normally several years, the shipyards went on producing before the crisis eventually hit them with a delay. This delay between the drop in demand and overproduction resulted in an overcapacity in the merchant fleet. A consequence of this overcapacity was a massive depreciation of the ships and technical insolvency for many shipowners such as the Danish shipowner TORM. Eventually, the market for new-builds halted and the willingness to make large investments in the current fleet reduced.

For the suppliers, this meant that the new-build activities had all but vanished and that the new market was in providing solutions for the operation of the existing fleet and helping the shipowners weather the storm by providing cost-effective/-reducing solutions.

CASE EXAMPLE: SLOW STEAMING

The capacity of the world fleet is based on the assumption that the vessels in the fleet are travelling at their rated speeds. To compensate for the lack in demand, while still keeping vessels in operation, many shipowners adopted the idea of "slow steaming", meaning running the ships at a reduced throttle.

Reducing the march speed by 20% can give fuel reductions of upwards of 30% [MAN PrimeServ 2012]. *The drawback is that most ship systems, such as the bulb on the hull, the hull coating and the main engine, are optimised to run at full steam. Due to this, problems can occur, requiring increased maintenance activities and modifications.*

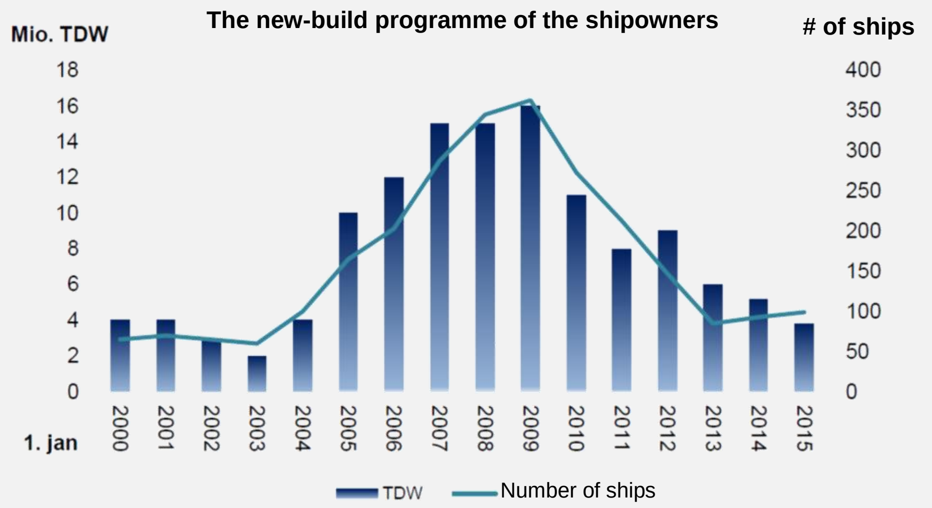


Figure 4: The newbuild activities of Danish shipowners – Ton dry weight (TDW) and number of ships (right hand axis). [The Danish Shipowners Association 2015]

2.3 THE PROTEUS CONSORTIUM

Despite an increased focus on supporting ship systems during their operations, the Danish suppliers were generally not particularly well suited for this new paradigm of operational support. Due to this challenge, the suppliers' branch association Danish Maritime and 10 Danish maritime suppliers joined forces with academic partners at the Technical University of Denmark (DTU) and Copenhagen Business School (CBS) to explore the opportunities for the Danish suppliers in the new market. On this basis, the PROTEUS (PROduct/service-system Tools for Ensuring User-oriented Service) innovation consortium was founded, based on financial support from the Danish Agency for Science, Technology and Innovation, the Danish Maritime Foundation; DTU; and in-kind support from the participating maritime companies.

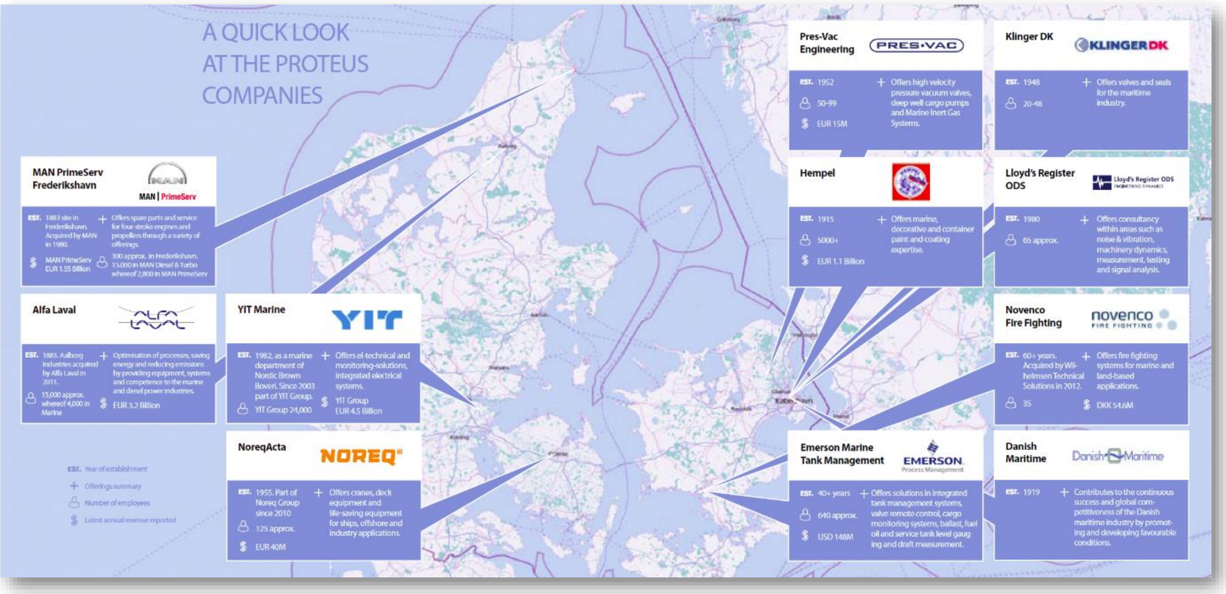


Figure 5: The PROTEUS consortium industry partners [Mougaard, L. M. Neugebauer, et al. 2013]

As the short description of the history for the Danish maritime branch showed, the Danish suppliers are characterised as having a strong knowledge of their technologies and the technical operation of vessels. In fact, it could be argued, that Denmark and its neighbours have the makings of a maritime "Silicon Valley" [Hviid 2013], where innovative technological ideas can be conceived and commercialised.

The objective of PROTEUS was to leverage the competencies and knowledge of the suppliers, find new ways of doing business and share best practice among the consortium partners.

To reach this end, an appropriate framework was needed. Therefore, the ideas found in Product/Service-Systems (PSS) research and practice were employed. In other industries, PSS has shown an ability to strengthen the businesses of manufacturing companies through a better understanding of customer operations and needs and through integration of products and services in combined offerings. PSS was at the very core of PROTEUS as well as the research conducted in this thesis. The next section sets out to explain PSS, its potential value and relevance to the maritime branch.

2.4 PRODUCT/SERVICE-SYSTEMS AS A STRATEGY FOR COMMERCIAL SUCCESS

Manufacturing companies are increasingly interested in improving customer value creation by adding services to products [O. Mont 2002]. Solutions where products and after-sales offerings are integrated with take-back systems are often called Product/Service-Systems or PSS [Mont 2000]. A PSS has the advantage that it can be designed to accommodate the true need of the customer [Tukker 2013; Bratt et al. 2014; Raja et al. 2013]. The combination of products and services means that more value can be created in a PSS than by a physical product alone. The process of moving from a product-centric strategy to a PSS strategy is typically referred to as *servitization* [Baines et al. 2010; Kindström 2010]. Servitisation has been positively correlated with improved profitability and ability to compete, for the companies adopting the strategy [Visnjic et al. 2014]. In a PSS, a pump manufacturer could change business model and instead deliver “water supply” or a jet engine manufacturer could start providing “power by the hour” instead of just engines – the latter being a widely cited example from Rolls Royce [Neely 2009].

At the core of PSS lies the intention to align the offerings of the suppliers with the needs of the customer [Wise & Baumgartner 1999; O. Mont 2002]. A key factor in this alignment is a proper understanding of the customer’s operations and the way in which the customer and other relevant stakeholders interact with the products and services. Only by including all relevant activities in the customers’ operations - also called the lifecycle - can well-functioning PSS solutions be created.

Research has shown a number of promising characteristics for PSS strategies, including increased resource efficiency [Bratt et al. 2014], improvements in operational performance and reduction of risks [Sharma & Molloy 1999]. Furthermore, PSS strategies can create new profit centres [Mont 2008], expand markets [Sharma & Molloy 1999], ensure sustained profitability and counteract marginalization [Tan et al. 2010]

Despite thee stated advantages, PSS has yet to get its breakthrough in most industries – despite the fact that industrial buyers are generally moving towards buying integrated solutions [Lindberg & Nordin 2008].

2.4.1 CUSTOMER NEEDS AND TRANSITION TO VALUE

Aside from ensuring satisfied customers, the identification of customer needs is also important to innovation [Griffin & Hauser 1993] in both Business to Consumer (B2C) and Business to Business (B2B) market segments. The discovery of needs (explicit and latent) is typically seen as the task of the marketing department of supplier organisations [Stanley & Narver 1998].

Many scholars have treated the difficulties involved in understanding complex needs [Hanna et al. 1995] and some argue that there is a need for better approaches to needs identification and understanding [Chong & Chen 2009].

One general challenge is the fact that needs change over time and that product development usually is based on a static understanding of the need at one point in time. This issue of temporality is particularly severe in markets where trends and developments in technology affect the characteristics of the demand [Angelis et al. 2012]. Furthermore, the customer is often not aware of his/her need making it exceedingly difficult to pin down [Tuli & Kohli 2007].

Even if the supplier has a thorough understanding of the customer’s needs, the relative importance of the needs is often interpreted differently by the supplier and customer. A more refined understanding of customer needs also leads to the challenge of needs diverging between customers and even between different stakeholders in the customer organisation [Lepak et al. 2007; Mittal et al. 1999]. This can result in the requirement for expensive tailoring of solutions.

In markets with such dynamics and opaque and divergent customer user needs, the survival and success of the supplier depends on continuous efforts to understand the customers' needs and activities.

The effort involved in deciphering the customers' needs and formulate attractive *value propositions* [Osterwalder et al. 2005] has long been a focus in business and operations management literature. Here, the notion of a *business models*, which translate used needs in to the components has been given extensive treatment [Magretta 2002; Osterwalder et al. 2005; Mont et al. 2006].

2.4.2 UNDERSTANDING VALUE IN PSS

In their study of the drivers for customer satisfaction in relation to PSS Raja et al [Raja et al. 2013] reveal the following dimensions:

- *Knowledge*: Experts in products/processes needed for assistance and performance gains.
- *Access:* Accessible as/when we need them, even outside normal business hours.
- *Relational dynamics:* Direct and long-lived business relationship, trust, relational skills.
- *Range of product- and service offerings:* A choice of offerings (products/services) better than competitors.
- *Delivery:* Meeting targets/dates, flexible delivery, expedited ordering.
- *Price:* More value for fixed price deals, possibility to negotiate, no extra charges.
- *Locality*: Proximity to customer, distance to operations.

The quantification of economic value in a PSS is made difficult by the flexible nature of services and complexity of offering supporting all relevant customer activities. Nevertheless, Through Life cycle Costing (TLC) has successfully been applied to PSS life cycles enabling an improved transparency and basis for decision making [Kreye et al. 2009]. The longevity of PSS contracts poses a challenge to TLC as uncertainty grows as the estimates go further into the future [Ferry & Flanagan 1991].

2.4.3 CONCRETE TOOLS FOR PSS UNDERSTANDING AND DESIGNING

At the core of PSS lie a number of tools and methods, which are commonly used for describing a given PSS and/or its prerequisites. In the context of PROTEUS, a workbook was created based on a thorough review of the PSS tools proposed by researchers and practitioners [Finken et al. 2013]. Many of the tools come from other fields, such as business management research and user experience methodology. Together, the tools form a strong basis for understanding the breadth and complexity of a given context and they provide ways for using this understanding for creating to create attractive solutions. The tools do this by expanding the notion of the a given products value creation in terms of the stakeholder- or "*actor*" network [Akrich et al. 2002], the changes in needs occurring over time in different activities [Vandermerwe 1993]. Figure 6 shows how a product can/should be understood, in terms of the user value it creates and how this basic value understanding can be expanded in different directions, to eventually encompass a full idea of the product's "*value in use*"[Baines et al. 2007].

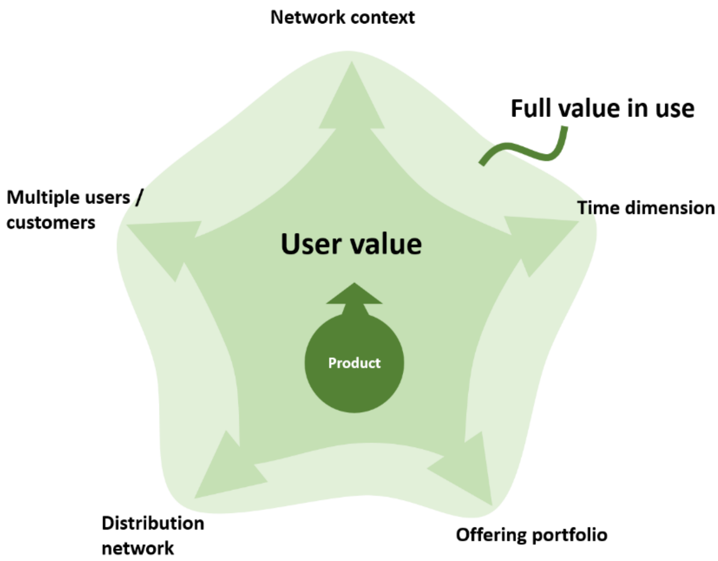


Figure 6: Dimensions of value in use [own]

Table 2 lists a number of tools adhering to these dimensions. Common for most of the tools is the use of visual formats appropriate for use in design workshops or as part of communications.

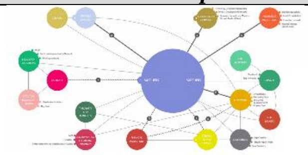
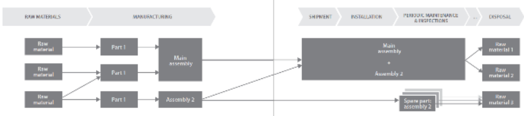
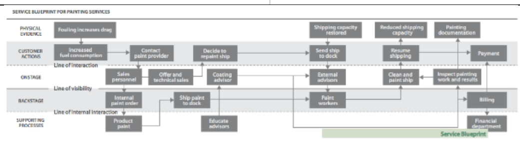
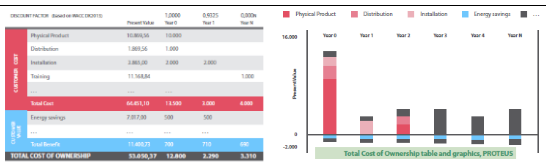
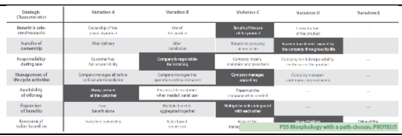
Tool	***Visual example***	***Reference***
Actor network (ecosystem map)		[Callon 1986; Akrich et al. 2002]
User Activity Cycle		[Vandermerwe 1993]
Product Life Gallery		[McAloone 2007]
Service Blueprint		[Bitner et al. 2008]
Total Cost of Ownership Chart		e.g. [Coster 2008]
PSS Morphology		[Tan et al. 2010]

Table 2: Tools in PSS design

2.5 PSS AND THE DANISH MARITIME BRANCH

The initial part out the PROTEUS consortium's work was aimed at gaining an overview of the characteristics of offerings among the consortium's participating companies. To this end, the current, imminent and future offerings of all companies were mapped in depth, in what was named the *service matrix.* Using grounded theory [Glaser & Strauss 1967], the matrices from all companies were analysed and a number of generic offerings were identified and related to Tan et al's [Tan et al. 2010] framework for categorising PSS solutions – see Figure 7. The framework is based on the notion, that manufacturers start from a product-centric outset (left side) and add offering dimensions of increasingly advanced types, eventually ending up with PSS solutions that directly support the business of the customer.

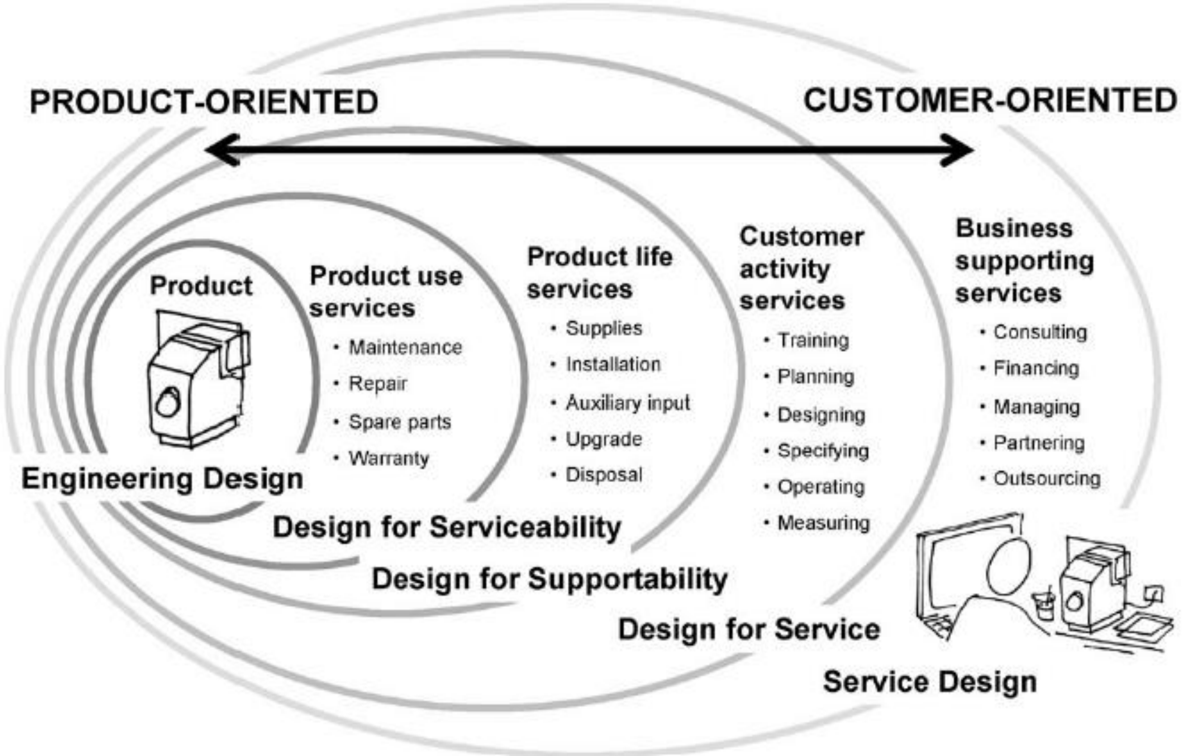


Figure 7: Tan et al's framework for categorising PSS offerings [Tan et al. 2010]

Figure 8 shows the result of this initial mapping of supplier offerings in PROTEUS. From a PSS perspective, the mapping was encouraging, as the suppliers were seemingly already active in providing certain services.

This quantitative observation was confirmed by the interviews conducted with consortium partners. These interviews showed a general inclination towards supporting the operations of the shipowners. However, at the same time it was clear that these customer-activity-oriented dimensions were mostly put in place as a differentiating feature in relation to competitors and only few companies had actually managed to turn a profit from their after-sales activities.

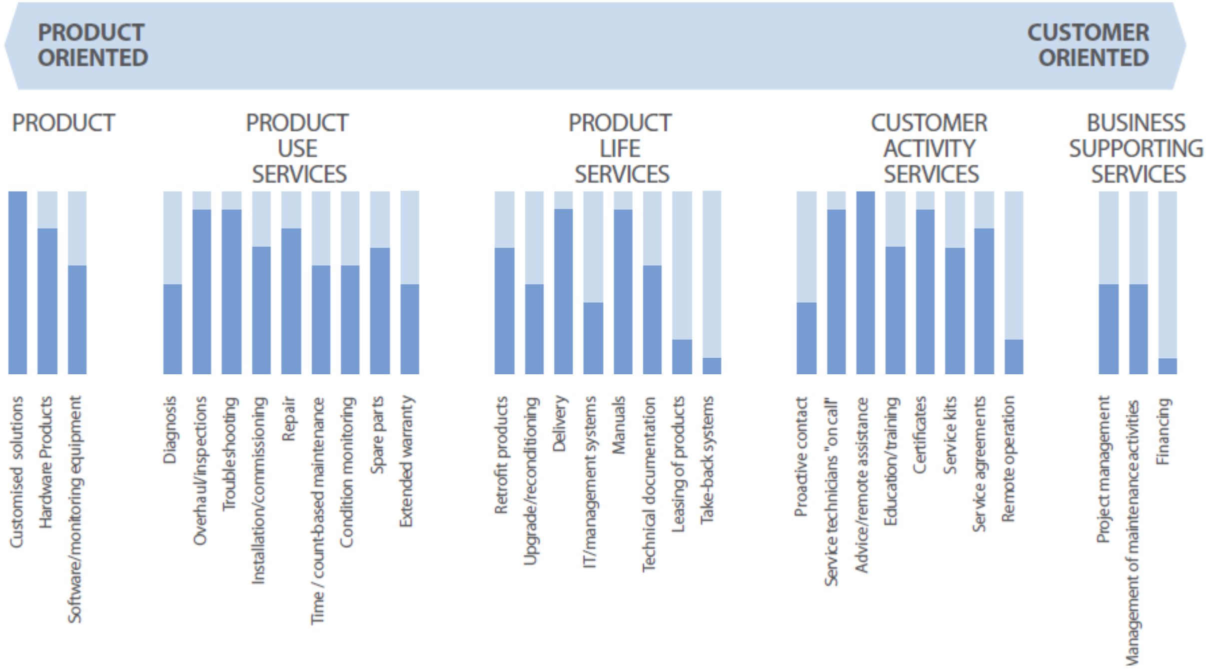


Figure 8: The consortium partners' offering portfolio at the beginning of PROTEUS [Mougaard, L. M. Neugebauer, et al. 2013]

In the general exploration of the branch, it became clear that there were examples of companies profiting on advanced PSS solutions; The Danish company Viking Life Saving Equipment was enjoying continued growth due to an ambitious and disruptive PSS strategy called "shipowner agreements". See more about this case in the case box.

Case example: Viking Life Saving Eq. – Shipowner agreements

Viking Life Saving Equipment has recently enjoyed substantial growth and commercial success. The company attributes a large share of this success to the increasing popularity of its so-called "shipowner agreements" for life rafts. In these agreements, the shipowner no longer owns or manages the life rafts aboard the vessel and therefore the significant challenges in complying with safety regulations and avoiding down time for the vessel is avoided.

Instead, Viking takes over the ownership and operation of the life rafts and gets paid by the shipowner to ensure compliance. In doing this, Viking can plan maintenance tasks and instead of offloading, refurbishing and loading the same rafts, the old rafts are simply exchanged for refurbished, certified rafts. This dramatically reduces the time the ship is stuck in port, thus saving the shipowner money.

Viking's success in using PSS can be seen as a confirmation that at least in some cases, there is a potential for profiting from PSS solutions in the maritime branch. According to Covin [Covin 1989] and the studies conducted in PROTEUS [Andersen et al. 2013], companies such as the Danish maritime suppliers who are faced with a hostile competitive environment, should not try to optimise operations and improve efficiency and productivity. Rather, they should pursue an *entrepreneurial recovery strategy* [Pearce Ii & Robbins 1994; Covin 1989], where products, services, organisation and management dimensions are reconfigured to address different needs. Viking's shipowner agreements can be seen as such a strategy.

There is an argument to be made for using PSS strategies in the current, hostile, regressive market. However, from the interactions with the suppliers in PROTEUS it was clear that despite an apparent willingness to pursue PSS opportunities, something else was standing in the way of PSS adoption in the industry. These barriers are discussed in the section 2.7.

2.6 ENTREPRENEURSHIP, CORPORATE R&D AND SPIN-OUTS

The term *entrepreneurial recovery* was introduced in the previous section without a discussion on what *entrepreneurship* is and what being *entrepreneurial* means to the Danish maritime supplier. In the context of this thesis, *entrepreneurship* can be thought of as *what the entrepreneur does.* According to Schumpeter [J. Schumpeter 1951], entrepreneurs identify new opportunities in the market and seek to exploit them. Shane et al [Shane & Venkataraman 2000] add to this by saying that the entrepreneur can also be someone seeking to utilise *new means-end relationships* in exploiting existing opportunities. In this definition, a maritime supplier seeking to exploit new commercial opportunities by way of new technology can clearly be seen as an *entrepreneur*. Chapter 3 treats the phenomenon of *entrepreneurship* in detail.

This definition of *entrepreneurship* is very reminiscent of the notion of *radical innovation* (as opposed to incremental innovation) [Schumpeter 2013; Leifer 2000], which deals with discontinuous improvements in either market (at the macro level) or in the technology. Some scholars even point to the necessity of *entrepreneurial* competencies in radical innovation [O Reilly & Tushman 2004]. In this innovation perspective, the M/S Selandia (treated in section 2.2.3) is a radical innovation because of the technological discontinuity – not the discontinuity of the market. A radical innovation is often a long-term initiative, to improve the growth of the organisation and ability to innovate [O'Hare et al. 2008].

Despite similarities, the *entrepreneurship* and *radical innovation* phenomena diverge in some areas; one particularly important difference is the *constructivist* perspective on opportunity, organisation and market [Bruyat & Julien 2001], which is the dominant logic in *entrepreneurship* research. The *constructivist* perspective is treated in detail in section 3.2.2. Another area is *entrepreneurship* research's focus on the individual and his/her traits (section 3.2).

Bearing these divergent characteristics in mind, the *radical innovation* literature does offer some relevant insights on how strategies involving significant changes (such as entrepreneurial recovery) can be implemented. O'Connor et al [O'Connor & DeMartino 2006] document how radical innovation can be organised in different ways – from *corporate R&D*, where the links between the part of the organisation dealing with radical innovation and the rest of the organisation is very strong to the *spinout.* In the *spinout,* the link is much weaker and the radical innovation organisation is likely to benefit less from the competencies and resources of the main organisation. Somewhere between these two extremes, the *innovation hub* exists; a separate, but manageable radical innovation organisation supported by corporate funds [O'Hare et al. 2008]. In short, radical innovation processes can be organised in a number of ways.

Regardless of type, reconciling culture and expectations for the *radical innovation* parts of the organisation with the strategies of the *incremental innovation* part of the organisation has proven to be difficult. In their study *of innovation hubs,* O'hare et al provide their conclusion on what is required for succeeding: "*Success factors were found to include: maintaining a low profile; starting with a small team and growing organically; maintaining a close relationship with the core organisation; and building a balanced range of competencies."* [O'Hare et al. 2008]. Although the conclusion is specific to innovation hubs, these success factors indicate that small, lean organisations, which are allowed to grow at their own rate are the most likely to succeed with radical innovation.

2.7 AN EMPIRICAL STUDY OF BARRIERS TO THE ADOPTION OF PSS

When trying to implement innovative offerings and business models, Danish suppliers have a unique advantage over their Far Eastern competitors, because of their unparalleled technological knowledge and a proximity to the customer, the shipowner. The latter dimension becomes all the more important, when considering the main identified challenge to PSS adoption in the industry: Conservatism.

In interviews with stakeholders across the branch, a general perception of the shipowners being conservative quickly became apparent. Suppliers proposing new, innovative solutions or technologies were simply not taken seriously and were liable to lose their bids for contracts.

After the conclusion of the PROTEUS consortium, new studies were conducted to find the underlying cause of this perceived conservatism. Specifically, a research project was initiated with a large Danish shipowner named TORM A/S. A 24-month long ethnographic study with two researchers was conducted. During these 24 months, more than 35 formal, in-depth interviews were conducted with employees in the entire organisation. Together with a mass of informal meetings between the researchers who worked in a *participant as observer role* (see section 1.3.3) and *documentary analysis* [Robson 2011], this study of TORM yielded an unprecedented understanding of the shipowner's view on innovative solutions and PSS. The *external generalisability* [Maxwell 2012] of the findings from TORM was partly confirmed through interviews with the Danish Shipowners' Association and another shipowner named J. Lauritzen.

The study of the shipowners enabled the drawing of a nuanced picture of the perceived conservatism of the shipowner and its root causes. Among these root causes were trust issues due to suppliers' exaggerated performance claims and previous contract breaches. As stated by the Danish Shipowners' Association:

> *"Sometimes you are promised service* around the clock, around the world [from a supplier], *but it is not realistic."*

Also, the lack of proper communication and knowledge sharing led to misunderstandings and sub-optimal solutions. Despite all of these issues, the shipowners interviewed both expressed a clear interest in PSS solutions and in collaborating with the suppliers:

As a performance manager in TORM states:

> *"it is a very conservative industry, and often big makers such as [Diesel Engine Manufacturers] are seen as bad [...] We think that they do not want to do anything good for us, the customers but that is not true; everyone is in this business to make money. But the way to look at it is this: When you have too much equipment from one supplier, we need to engage with him and make a partnership."*

2.8 CHOOSING PATHS

Based on the explorative study of the Danish maritime branch, two potential paths for continued research were identified. These paths are now described along with the considerations made in picking one over the other, as the basis for the main research path of this thesis.

From the above description of the maritime branch, the opportunity that lies in PSS and the challenges found (conservatism, trust, lack of communication), it was clear that there was a great potential in further exploration of the shipowners' view on PSS and in using the shipowner as a starting point for adoption of PSS solutions in the branch. Therefore, the first proposed research path was:

> ***1st Potential research path****: Exploring the customers' view on PSS solutions.*

Knowing the customers' view on solutions would be of great help to the Danish supplier companies, but one other important component would still be missing, if the Danish suppliers were to enjoy a sustained competitive advantage; namely the ability of the suppliers to leverage their technological advantage in building disruptive businesses. For this reason, a 2nd potential research path was identified.

> ***2nd potential research path:*** *Seeking an understanding of entrepreneurial processes dealing with advanced technology.*

This much broader research path aims to understand the way in which new technology is exploited and used as a basis for new businesses or business areas. For this knowledge to be relevant for the maritime suppliers, it has to be described in terms of the process – as opposed to the boundary conditions or contextual dimensions. This is to ensure that the result of the research effort is practical in nature and applicable to the operations (processes) of the supplier companies.

In extension of the ethnographic study conducted at TORM, a longer-term research project was at the time of writing established in collaboration with the shipowner. The goal of this project was very much in line with the 1st potential research path. For this reason and because of the conclusion that major changes need to occur for the maritime suppliers in relation to technology exploitation, the rest of this thesis will be concerned with the 2nd potential research path.

In line with the virtues mentioned for PSS and the potential for the framework in supporting the activities of the maritime suppliers, the following hypothesis is formulated:

> ***H1:*** *Entrepreneurial processes dealing with advanced technology can benefit from the tools and methods found in design and innovation research in general and PSS in particular.*

The validity of this hypothesis will be discussed when the necessary empirical basis has been established.

2.9 CONCLUSION: PSS AND THE NEED FOR NEW WAYS OF DOING BUSINESS BASED ON TECHNOLOGY

In this chapter, the antecedents of the Danish maritime branch and its success have been traced. Technological innovation has played a large part in the strong international position currently held by the branch and the branch is still a world leader in terms of technological knowhow.

Economic crises, globalisation and the emergence of competitors in the Far East have led to a decline in new build activities in Europe and the suppliers can no longer rely on the shipyards as their main source of business. Instead of assisting with building new ships, the suppliers are increasingly active in supporting the operational activities of the existing fleet.

This move from new builds and shipyards-centred activities to international support of shipowners has brought a mass of opportunities, but also challenges for the Danish maritime suppliers, who are struggling to find their bearings. To help the suppliers in understanding and profiting off the new market order (operational support), the PROTEUS consortium was founded as a collaboration between several suppliers and two universities. PROTEUS was based on the idea of Product/Service-Systems (PSS) as a framework for understanding how businesses can capitalise on supporting the operations of the customer with products and services.

Despite providing a number of potential benefits for the suppliers, a number of barriers were found for PSS in the maritime branch. Among these were problems of trust in the relationship between supplier and customer (the shipowner) and practical difficulties in upholding the agreements required for maintaining a PSS solution.

Two research paths were suggested: One aimed at improving the understanding of the shipowners’ needs. The second, more ambitious path was aimed at finding out how maritime suppliers could leverage their superior technological insights in building new, competitive businesses.

Based on the argument that significant changes are needed for the suppliers to succeed, the second path, dealing with the process of creating entrepreneurial ventures, was chosen as the focus for the rest of the thesis.

2.10 REFLECTION ON CHAPTER CONCLUSIONS

The suggested research paths are based on the conclusion that the current market situation in terms of competition from Eastern competitors and the erosion of the value chain (closing of shipyards) is severe enough to mandate an entrepreneurial recovery strategy. The PROTEUS consortium has been 4 years underway and in that time the global economy took a turn for the better with many suppliers are seeing positive developments in order books turnover. A large portion of the empirical data resulting from PROTEUS was gathered at a time where the economic forecasts for the branch were bleak and this has inevitably influenced the conclusions of the chapter.

Empirical studies of the branch in its current situation might lead to the conclusion that suppliers should pursue *retrenchment strategies* instead of *entrepreneurial strategies* [Pearce Ii & Robbins 1994]. As this data is not available, there is no way to substantiate these speculations and the only option for the thesis is to build on the existing (albeit potentially outdated) data.

Regardless of economic situation, the fact remains that the maritime suppliers are now operating in a globalised and commoditised market, where technological knowledge and PSS solutions have proven to be sources of competitive advantage. With this in mind, it is safe to proceed to the next parts of the thesis with a sustained focus on technology venturing.

CHAPTER 3:
ENTREPRENEURSHIP AND TECHNOLOGY

RQ 2.1:
What type of support does the tech venture require to succeed with entrepreneurial strategies?

RQ 2.2:
Can entrepreneurship research provide the necessary (process) support?

RQ 2.3:
How can entrepreneurship research be strengthened to better cater to the needs of technology venture processes?

To understand how entrepreneurial strategies can help Danish maritime suppliers, one must first understand the field of entrepreneurship research and its relation to the design and innovation research fields, which are accustomed to dealing with technology and its role in commercial success.

3.1 CHAPTER RESEARCH DESIGN

This chapter adopts a combination of literature studies and qualitative ethnographic approaches in building the arguments and supporting the discussions.

3.1.1 LITERATURE STUDY

The first two sections deal with the conceptual understanding of entrepreneurship and entrepreneurship processes. These sections are based on an in-depth study of the literature in the field of entrepreneurship. Following the guidelines of Robson [Robson 2011], keyword searches were used to find initial candidates, which were then filtered based on reading the abstracts. Highly cited papers were given priority, but more recent papers with fewer citations were also included to ensure an updated understanding of the field.

From this starting point, new publications of interest were discovered by reading the papers and identifying relevant papers in the discussions and reference lists. Also, the forward citations, which are listed on Google Scholar (http://scholar.google.com), Scopus (http://www.scopus.com) and on Web of Science (http://www.webofscience.com) were used to identify newer publications building on the work described in a given paper.

To ensure that a good understanding of the field in mention had been established, the software CitNetExplorer (http://www.citnetexplorer.nl) was used. This software uses the meta-data for a Web of Science search query to visualise the central publications along with their relations in terms of citations. As an example, Figure 9 shows such a visualisation based on the 504 publications that have cited William B. Gartner's 1985 paper *"A conceptual framework for describing the phenomenon of new venture creation"* [Gartner 1985] (chosen here due to its relevance for the research and its high number of citations).

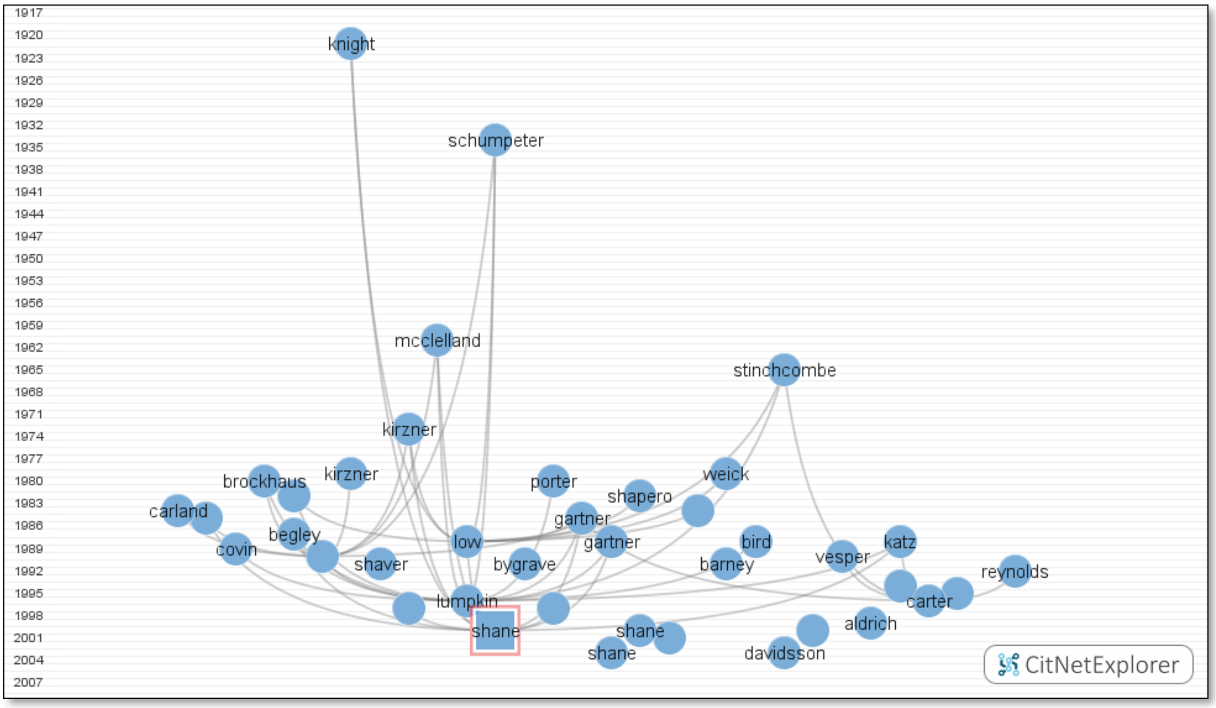


Figure 9: An example of a bibliographic visualisation of works citing William B. Gartner [http://www.citnetexplorer.nl]

The software places closely related publications near each other in the horizontal direction. The vertical direction is a timeline indicating when the paper was published.

3.1.2 AUTO-ETHNOGRAPHIC STUDY

The last section of this chapter that deals with the role of advanced technology in entrepreneurship also builds on the literature study approach described above. However, as will be apparent to the reader in the first two parts of the chapter, the area of entrepreneurship research suffers from a lack of empirical data – especially when it comes to entrepreneurial ventures dealing with advanced technology of any kind, including maritime technology. For these reasons, it was decided that a longitudinal ethnographic study should be set up, to provide an empirical reference for the theoretical discussions in literature.

3.2 PERSPECTIVES ON ENTREPRENEURSHIP

The notion of entrepreneurial activity has its origins in the works of Schumpeter [J. A. J. Schumpeter 1951; Schumpeter 1934]. The Schumpeterian entrepreneur is a person engaged in identifying and exploiting new opportunities by (re-)configuring available resources. The notion of an *opportunity* is at the core of most scholarly work in entrepreneurship – indeed, as stated by [Moroz & Hindle 2012], the notion of opportunity is one of the few common traits across a very diverse and unconsolidated field. Even so, the idea of an opportunity is also the basis for discussion. Some [Gartner 1985; J. A. J. Schumpeter 1951] define entrepreneurship as an inherently commercial activity, where financial profit is the end goal. Others [Sarasvathy 2008; Austin et al. 2006] have adopted a wider interpretation of value, including social value (non-profit) as a goal for entrepreneurship.

As the field has evolved, most scholars have evolved to dismiss the notion that the opportunity as an objective feature of a given context [Shane 2012]. As a consequence of this realisation, the field of entrepreneurship has moved from looking primarily at the traits of the entrepreneur and his/her ability to identify opportunities to a more holistic view, where the entrepreneur is just one (very crucial) piece of the puzzle [Gartner 1988; Shane & Venkataraman 2000]. A number of scholars have proposed theoretical frameworks for understanding entrepreneurship as a phenomenon. Below, three of these are treated to provide an overview of the central components of the entrepreneurial phenomenon.

3.2.1 A CONCEPTUAL FRAMEWORK FOR ENTREPRENEURSHIP AS A PHENOMENON

Gartner provides a widely used framework for understanding the components of entrepreneurial activity (the *emergence of new ventures*) [Gartner 1985]. The framework has been built as an attempt to create a common conceptual reference for the many different and often unrelated paths seen in entrepreneurship research. In Gartner’s argument, one component cannot be treated in isolation. The features of the framework are shown in Figure 10. Each will be treated in turn below.

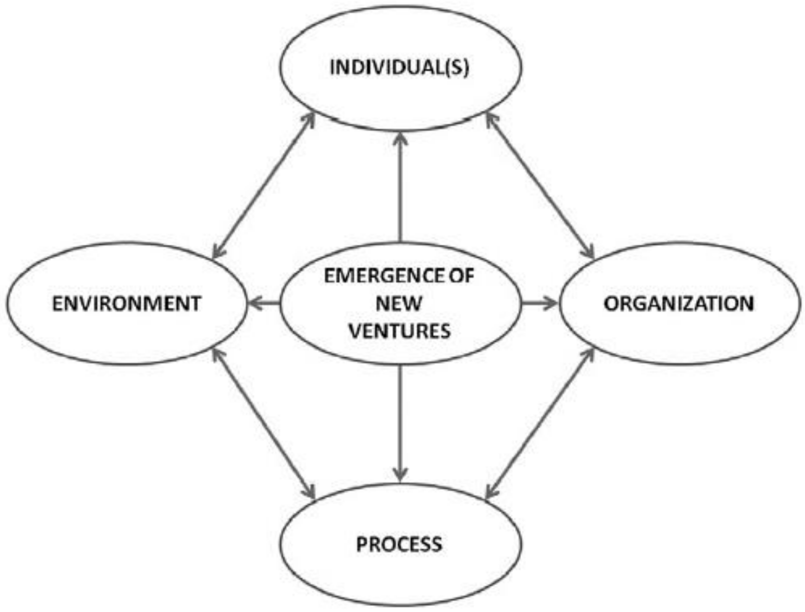


Figure 10: Gartner's conceptual description of entrepreneurship process [Gartner 1985]

3.2.1.1 INDIVIDUAL(S)

This component of the framework refers to the persons making up the entrepreneurial team. Many efforts have been put into describing and understanding the psychological profile or traits of the entrepreneur as well as his/her background (e.g. [S. Shane 2000; Jo & Lee 1996]). The types of questions being treated in this area include "Do certain individuals have a propensity toward increased awareness of opportunities?"; "How does the prior knowledge of the entrepreneur affect his/her ability to succeed?"; "Are entrepreneurs less risk-averse than non-entrepreneurs?" etc.

3.2.1.2 ENVIRONMENT

In Gartner's definition, the environment consists of the external influences that can affect the success of failure of the venture. This could be regional policies, availability of capital, technical competencies etc. Furthermore, in Gartner's view, the environment consists of elements that cannot be affected by the entrepreneur. If the entrepreneur is able to affect an element, it should be considered as part of the organisation component of the conceptual framework.

3.2.1.3 ORGANISATION

Gartner states that the type of business (service, manufacturing, wholesale, retail etc.) is an important factor in understanding the emergence of a new venture. The business model [Magretta 2002; Osterwalder et al. 2005] and its importance to businesses – new and established – can be seen as a more advanced perspective on Gartner's idea of the *organisation.*

3.2.1.4 PROCESS

Finally, the emergence of the new venture is dependent on the processes undertaken by the entrepreneurs. Gartner lists six generic features of entrepreneurship processes that can appear in any order: *The entrepreneur locates a business opportunity, the entrepreneur accumulates resources, the entrepreneur markets products and services, the entrepreneur produces the* *product, the entrepreneur builds and organisation* and *the entrepreneur responds to government and society.* In Gartner's later works he underlines the particular importance of the process perspective [Gartner 1988] and the lack of practical insights into the activities of the entrepreneur.

3.2.2 THE CONSTRUCTIVIST PERSPECTIVE ON ENTREPRENEURSHIP

More recently, Bruyat & Julien have provided a model for understanding the components of the entrepreneurial phenomenon [Bruyat & Julien 2001]. In their framework (shown in Figure 11), many of the same components can be identified, but a few important differences are worth noting. These differences are treated below.

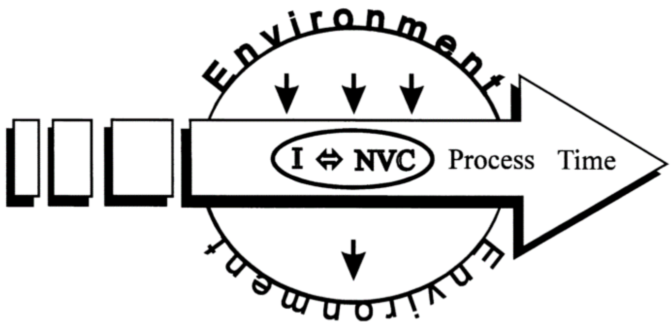


Figure 11: Bruyat & Julien's model for entrepreneurship as a phenomenon [Bruyat & Julien 2001]

3.2.2.1 THE CONSTRUCTIVIST STANDPOINT

Whereas many works on entrepreneurship see the individual (the entrepreneur) and the opportunity as disparate things, Bruyat & Julien see them as highly interdependent elements, which form the core of the entrepreneurship phenomenon. The opportunity - or *new value creation* (NVC) in Bruyat & Julien's terminology – only exists because it has been identified and/or created by the entrepreneur. The entrepreneur's ability to do this is a function of experience, cognitive abilities and other individual characteristics. However, just as the opportunity is seen as a function of the entrepreneur, the opposite is also true: The entrepreneur and his/her characteristics are functions of the opportunity and the emerging venture, which will shape the entrepreneur.

The dialogue and co-creation between the entrepreneur and the opportunity are the drivers for the entrepreneurial process, which in turn unfolds in the overall environment. Gartner defines the environment as factors that the entrepreneur cannot influence, but which influence the emerging venture. Bruyat & Julien see the environment as something that can be changed by the (successful) entrepreneurship process.

3.2.3 EFFECTUATION IN ENTREPRENEURSHIP

The constructivist perspective on entrepreneurship is brought even further by Saras D. Sarasvathy, who in her research studied the cognitive strategies of expert entrepreneurs [Sarasvathy 2008; Dew et al. 2009]. Her studies were based on so-called think-aloud experiments, where the subject is asked to solve a task and verbalise the actions taken. The expert entrepreneurs were chosen based on their track record; they had to have successful exits (the venture being sold to another company) or initial public offerings (IPO).

These studies led to the recognition that the expert did not perceive the opportunity as something to be identified and then exploited. Rather than relying on market reports and forecasts, the serial entrepreneurs tended to start with their immediate surroundings and themselves when investigating the potential of an idea. The questions "*Who am I?*", *"What do I know?"* and *"Whom do I know?"* were the starting point of what Sarasvathy has coined as an *effectual* strategy for opportunity discovery – as opposed to a *predictive* strategy.

Sarasvathy's work adds a cognitive dimension to the understanding of entrepreneurship and it resonates well with the *constructivist* perspective adopted by Bruyat & Julien [Bruyat & Julien 2001]. Sarasvathy argues that early stage entrepreneurs are most likely to succeed by primarily using *effectual* strategies supported by limited use of *predictive* strategies. As the company matures, the *predictive* strategies will become increasingly useful as the market becomes clearer. Figure 12 shows Sarasvathy's dichotomy of *effectual* and *predictive* strategies for identifying customers, segments and markets.

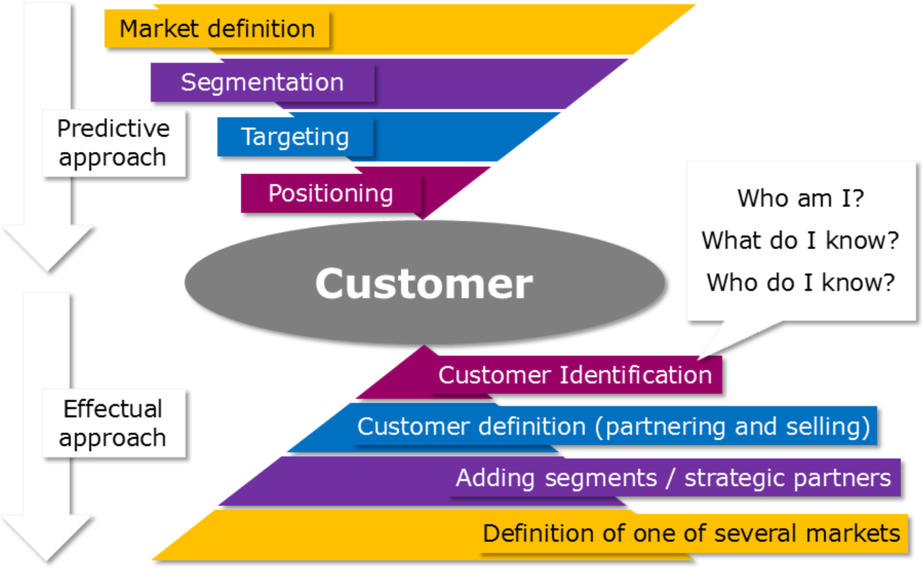


Figure 12: Predictive versus Effectual strategies according to – adapted from [Sarasvathy 2008]

Along with her overall distinction between *effectual* and *predictive* cognitive strategies, Sarasvathy's studies lead to the formulation of five principles of effectual thinking, which are observed in the cognitive strategies of the expert entrepreneurs. These principles can be seen as useful heuristics for the entrepreneur trying to build his/her venture.

3.2.3.1 BIRD IN HAND

In accordance with the cognitive strategies employed by expert entrepreneurs, this principle is about pursuing the immediate opportunities of the venture – as opposed the more abstract and commercially attractive opportunities. As the saying goes: "*a bird in hand is worth two in the bush*".

3.2.3.2 PATCHWORK QUILT

Just as Gartner and Bruyat & Julien [Gartner 1985; Bruyat & Julien 2001] describe the emergence of a venture from a heterogeneous set of components, so does Sarasvathy. Her *patchwork quilt* principle refers to the fact that the solution is constantly changes as new stakeholders are enrolled and new perspectives considered. This eventually leads to a cohesive solution that represents the interests and needs of central stakeholders, thus increasing the likelihood of success.

3.2.3.3 AFFORDABLE LOSS

Failure is a fact of life for the entrepreneur and even expert entrepreneurs know that the chance of success is low [Jo & Lee 1996]. Instead of thinking of investments into the venture as a means to create a return at a certain level of risk, expert entrepreneurs base investments on what they can afford to lose at a given point.

3.2.3.4 LEMONADE

The future of an entrepreneurial venture is by definition uncertain. Sarasvathy speaks of an *isotropic* environment, where the factors that will eventually prove to be important to the entrepreneurial venture are unintelligible and unidentifiable to the entrepreneur. Therefore, the successful entrepreneur should thrive in contingent environments where different new discoveries and learnings can quickly change the platform on which the proposed solution rests. Rather than being threatened by such contingencies, the entrepreneurs should try to leverage them. The principle's name comes from the example of the fruit merchant, who was given a batch of sour lemons instead of oranges. Instead of closing down, the merchant chose to make lemonade and sell this instead of fruit.

3.2.3.5 PILOT IN PLANE

The last principle in *effectuation* strategies deals with the expert entrepreneurs' propensity toward choosing solutions and avenues that depend largely on factors within the control of the entrepreneur. From the *constructivist* perspective, this is a sensible strategy as the entrepreneur (the "I" in Bruyat & Julien's terminology) maintains the ability to affect the opportunity (the new value creation or "NVC").

3.2.4 EFFECTUATION AND THE SCIENCES OF THE ARTIFICIAL

Philosophically, Sarasvathy has drawn extensively upon the works of Herbert Simon and his book *Sciences of the Artificial* [Simon 1969]. In Simon's perspective, the science of the artificial deals with "*objects in which human purpose as well as natural laws are embodied"*. Simon characterises an artefact by one of the following:

1. *Artificial things are synthesized (though not always or usually with full forethought) by man.*
2. *Artificial things may imitate appearances in natural things, while lacking in one or many respects the reality of the latter.*
3. *Artificial things can be characterised in terms of function goals and adaptation.*
4. *Artificial things are often discussed, particularly when they are being designed, in terms of imperatives as well as descriptives.*

Simon argues that such human artefacts are important to consider in fields of research ranging from the social sciences to economics and beyond. Artefacts shape human behaviour and they are themselves a consequence of human action. Indeed, this action of synthesising an artefact to serve a certain purpose can be deliberate. This process of creation is called *design.*

In Sarasvathy's perspective, entrepreneurship should be considered a science of the artificial, where the artefacts of interest are the entrepreneur and the firm. This resonates with Bruyat & Julien's *constructivist* notion that a co-creation occurs between the entrepreneur and the new value creation.

3.2.5 A DIVERSE FIELD LOOKING FOR COMMON, UNIQUE GROUNDS

The field of entrepreneurship research resides in a space between a number of other fields, such as strategic management, organisational behaviour, economic research, cognitive psychology and social studies. Several attempts have been made to conceptualise how these different dimensions weave together and form the basis for a distinct field.

From its Schumpeterian outset, the field has been centred on the relation between the entrepreneur and the opportunity – i.e. the potential value to be created in a given context. The nature of this relation has changed over time from one-way opportunity recognition over a dialogical view to a constructivist view where the opportunity and entrepreneur are co-created. In recent works, scholars have drawn convincing parallels between Simon's notion of a *science of the artificial* and the creation of the entrepreneur and the opportunity.
The perception of what value entails has also changed since the early days of entrepreneurship research. Value is no longer perceived as merely economic and social views on entrepreneurship are now widely acknowledged.

The entrepreneurship process dimension is a central part of all the theoretical frameworks presented. Still, several scholars in the field point to the fact that processes are generally poorly understood and that this reduces the relevance of the research to practitioners. For this reason, the entrepreneurial process dimension will be given special treatment in the next section.

A similar thing can be said about the role of technology in entrepreneurship research. The role of innovation, i.e. the commercialisation of technical invention, has been considered as part of the field since its conception. Despite this, the role of technical development and technology in entrepreneurship seems to be largely unaccounted for. As this dimension is crucial for Danish maritime suppliers, the field of design and innovation research and its views in technology will be introduced and discussed in the last sections of this chapter.

3.3 ENTREPRENEURSHIP PROCESS RESEARCH

As stated by Moroz & Hindle [Moroz & Hindle 2012], entrepreneurship is "*... fundamentally an action based phenomenon, which involves a highly interrelated set of creative, strategic, and organizing processes".* The deliberate process of achieving new value creation defines the entrepreneur – the person merely thinking about starting a company is not an entrepreneur [Bruyat & Julien 2001]. In other words, the practice of the entrepreneur is crucially important. Still, as Bygrave states in his contribution to the Handbook of Qualitative Research Methods in Entrepreneurship [Neergaard & Ulhøi 2007]: "*...only 10 percent* [of studies in "A-class" journals] *were based on interviews and less than 1 percent on observation."* In Bygrave's view, the predominantly theoretical approach produces *"...mostly pedestrian findings that are of little or no interest to practitioners."* It seems then, that the field of entrepreneurship research currently has severe limitations in providing useful support for entrepreneurial ventures – such as Danish maritime suppliers. Indeed, Bygrave calls for entrepreneurship scholars to *"...read some recent issues of our leading journals and ask* *yourself what have you learned that is important to your teaching and advising and the practice of entrepreneurship."*

3.3.1 THE FRAGMENTED FIELD OF ENTREPRENEURSHIP PROCESS THEORY

Building on Bygrave's call for practice-based entrepreneurial process theories, Moroz & Hindle [Moroz & Hindle 2012] try to consolidate the current state of the art in entrepreneurship process theory. The study surveys 32 peer reviewed, published works of scholars dating back to 1976. Moroz & Hindle reach a number of significant, albeit slightly ominous conclusions, which will be treated below.

3.3.1.1 LACK OF THEORETICAL CONSENSUS

In their evaluation of entrepreneurial process studies and theoretical contributions, Moroz & Hindle try to identify if the contribution is unique to entrepreneurship or if can be seen as a subset of other areas of research. The pretence is that for a the field of entrepreneurship to be valid and useful, it needs to provide something that other fields, such as management research, economic research, innovation research etc. do not already cover. If nothing unique can be said for entrepreneurship research and the phenomenon it deals with, it will be exceedingly difficult conduct research in a coherent manner.

In the analysis, Moroz & Hindle found that only four of the 32 studies treated dealt with the question of what is distinct about the entrepreneurial process. However, even the theoretical frameworks presented there could, at least in part be constructed from concepts introduced in other research fields. In certain cases – e.g. Gartner's conceptual framework presented above [Gartner 1985] – the distinctiveness of the entrepreneurship phenomenon is not to be found in the treatment of each component (organisation, environment etc.), but rather in the co-evolution of all components at once.

Moroz & Hindle generally conclude that the entrepreneurship research field is characterised by a "*hodgepodge*" of theories showing *"few cumulative effects"* despite the 40-year history of the research field.

Despite this disparateness of theoretical standpoints, Moroz & Hindle do manage to identify six points of convergence, which should be considered and included in future research efforts:

- The relationship between individual and opportunity.
- The need for critical assessment of the disruptive and transformative role of knowledge.
- The creation of new business models (as opposed to adapting existing) is at the core of entrepreneurial process.
- The temporality of the entrepreneurship phenomenon is crucial as opportunities, entrepreneurial competencies and other central concepts will change over time.
- Action is a key element of entrepreneurship - new value is never created by the entrepreneur merely thinking about it.
- The contextual setting for the entrepreneurial process is crucially important as the process unfolds based on the entrepreneur's understanding of interaction with the context.

3.3.1.2 POOR EMPIRICAL FOUNDATIONS

Perhaps the most crucial finding of Moroz & Hindle is the fact that only 9 out of 32 models examined are based on empirical evidence. The rest of the models are theoretical derivatives, which, in light of the theoretical fragmentation of the field described above, can hardly be seen as a solid foundation. In the words of Moroz & Hindle: *"The majority of* [the models] *can be fairly described as artefacts unsupported by systematic evidence."*

According to Moroz & Hindle, this poor empirical grounding leads to theory and process models that have few practical implications.

Process model types

Moroz & Hindle also try to classify the process models provided in entrepreneurship research. Inspired by Steyaert's categories for theories in process-based studies [Steyaert 2007], a simple taxonomy for process models is created – see
Table 3.

Category	***Description***
Stage Model	Divide into a priori stages major tasks or phases; One major weakness is that they tend to narrow the scope of investigation and that temporal orders of events do not fit the proposed stages and/or often overlap.
Static Framework:	Characterises the overall process of venture creation without examining the sequence of activities, consists of a limited set of variables connected by speculative causal links (e.g., Gartner, 1985); process oriented but do not capture sequence of dynamics.
Process Dynamics:	Employs qualitative methods to examine how and why variations in context and process shape outcomes; often interpretive, temporal, and change oriented.
Quantification Sequences	Is a historical sequence based approach of the new venture creation process; this approach does not allow researchers to understand the dynamics of how antecedent conditions shape the present and the emergent future within the process; Carter, Gartner, and Reynolds (1996) identified three broad activity profiles: up and running, still trying and given up.
Other	Any models that do not fit within the definitional parameters of the above four models.

Table 3: Moroz & Hindle's taxonomy for process models

Table 4 shows the frequency of the different categories in the taxonomy. Stage models of various types are widely used (12 out of 32) in the models examined. The same goes for static models (11 out of 32) that represent the process and its components without accounting for the temporal dimensions and order of the process. A number of theories (8 out of 32) deal with process dynamics in the form of cyclical or heuristic models - such as e.g. *Effectuation*.

Model Class	***#***	***Empirical/conceptual***	***#***	***Level of generality***	***#***	***Level of analysis***	***#***
Stage Models	12	Conceptual	21	Specific to context	1	Individual	25
Static frameworks	11	Empirical	10	Broadly specific	11	Group or team	3
Process Dynamic	8	Qualitative	10	General but mixed	1	Organisation	21
Quantification sequence	1	Quantitative	3	General	16	Meso environment	7
Other	0	Both	3	General and distinct	4	Macro environment	2
Total	31	Practical	7			Multiple	16

Table 4: Frequency of models within Moroz & Hindle's categories

A need for improving process research methodology

Aside from pointing out the general lack of empirical backing for entrepreneurship process theories and models, Moroz & Hindle point out that the level at which process research is conducted in entrepreneurship field is generally oblivious to the ideas already established in research on the role and nature of processes in human affairs (e.g. [Bergson 1889; Heidegger 1927; Whitehead 1929]). Moroz & Hindle state that the current poor state of process research is due to four aspects:

1. A lack of access or support for longitudinal research.
2. Fewer management-trained scholars with event-driven methods training.
3. The commitment of time and resources required to conduct in-depth discovery of process events.
4. Little understanding of what constitutes good theory, methods, and practice.

3.3.2 PHILOSOPHICAL AND METHODOLOGICAL INADEQUACIES IN ENTREPRENEURSHIP PROCESS RESEARCH

As the above sections attest, the process dimension of the entrepreneurial phenomenon is crucial to the overall epistemological developments in the field. As stated by Gartner [Gartner 1985], the isolated treatment of single dimensions of the entrepreneurial phenomenon is unlikely to yield results of use to the field as a whole. Therefore, a poor understanding of the process dimension is a problem – not just to process focused scholars, but also entrepreneurship scholars dealing predominantly with other dimensions.

Despite its importance, entrepreneurship process remains to be a field of poor empirical foundations and theoretical inconsistencies [Neergaard & Ulhøi 2007]. In their in-depth study of the state of the art in process research, Moroz & Hindle confirm this assertion and go on to investigate some of the antecedents for the field's current state. Their analysis showed that researchers are methodologically and philosophically challenged in trying to understand the process of entrepreneurship.

This leads to the conclusion that for the area of entrepreneurship research to become directly relevant to practitioners, such as Danish maritime suppliers, the process dimension needs to be understood. For this to happen, researchers need new, efficient ways for describing the process as it unfolds and for building coherent theories.

3.4 TECHNOLOGY AND ENTREPRENEURSHIP RESEARCH

The role of advanced technology in entrepreneurial ventures has received some attention [Hindle & Yencken 2004; Song et al. 2010; Park 2005a]. However, as in the case in the general field of entrepreneurship research, the empirical underpinnings for the identified studies are generally lacking. For this reason, it was decided that an empirical study of entrepreneurship processes dealing with advanced technology should be conducted in order to provide a practical reference for the theoretical discussions in literature.

In a review of technology entrepreneurship literature, Bialetti [Bialetti 2012] concludes that the research on *technology entrepreneurship* has yet to find its way in to high ranking journals and that the contributions to entrepreneurship- and innovation research from the work reviewed is very limited. Bialetti goes on to suggest a useful definition of *technology entrepreneurship* that makes the field of research distinct from *entrepreneurship* field in general:

> *"Technology entrepreneurship is an investment in a project that assembles and deploys specialized individuals and heterogeneous assets that are intricately related to advances in scientific and technological knowledge for the purpose of creating and capturing value for a firm."*

This definition is reminiscent of the firm-centric concept of entrepreneurship put forth by Gartner [Gartner 1985], but adds the important link between the entrepreneurial effort and how it creates value based on advances in scientific and technological knowledge. Next, the concept of *technology* and its role in *entrepreneurship* will be discussed.

3.4.1 THE NATURE AND RISKS OF TECHNOLOGY

As regards to technology, this thesis takes its point of departure in Arthur's concept of new technology as a combination of existing technologies and integration of natural phenomena to fulfil human purposes [Arthur 2009]. This definition helps link the concept of technology with value creation.

To understand the amount of risk related to a given technology, one first needs to understand the nature of the technology, its maturity, its importance to the venture and the challenges involved in developing it. The Technology Readiness Levels (or “TRLs”) proposed by Mankins [J. C. J. Mankins 1995], provide a specific set of guidelines for gauging the maturity of a technology. In later work, Mankins [J. C. J. Mankins 2009] attempts to provide a more holistic view of technological risk. In this framework, Mankins attempts to develop and concretise the widespread “risk matrix” format [L Anthony Tony Cox 2008], which enables the evaluation of a given technology, based on two variables: Probability of R&D failure (Pf) and the consequences of R&D failure (Cf).

Risk Matrix dimension [L Anthony Tony Cox 2008]	***Dimensions from Mankins*** [J. C. J. Mankins 2009]	***Range*** [J. C. J. Mankins 2009]
Pf Probability of R&D failure	**R&D3** R&D degree of difficulty	*from* **1**=Very low degree of difficulty anticipated in achieving research and development objectives for this innovation. *to* **5**=The degree of difficulty anticipated in achieving R&D objectives for this innovation is so high that a fundamental breakthrough in physics, chemistry/etc. is needed.
Cf consequences of R&D failure	**TNV** Technology Need Value	*from* **1**= not critical at this time. *to* **5**= critically important.
	TRL Technology Readiness Level	*from* **1**=Basic principles observed and reported. *to* **5**=Actual system “flight proven” through successful mission operations.

Table 5: The dimensions of Mankins’ technology risk assessment framework.

Mankins attempts to improve the basis for this evaluation by describing the dimensions (Pf and Cf) in terms of TRLs as well as two novel concepts – namely Technology Need Value (TNV) and R&D degree of difficulty (R&D3). The former is a measure of how valuable the technology is the proposed system. The R&D3 measure is an indication of how straightforward the development of the technology will be. See more on the measures in Table 5. Mankins’ notion of natural phenomena (as defined for R&D3) as a basis for radical technological development is very much in line with Arthur’s original definition of technology. Figure 15 shows how TRL, TNV and R&D3 relate to the dimensions Cp and Cf of the risk matrix. Note that the TRL is expressed as a delta, meaning that the maturity itself is used in terms of the difference between the desired and the current maturity.

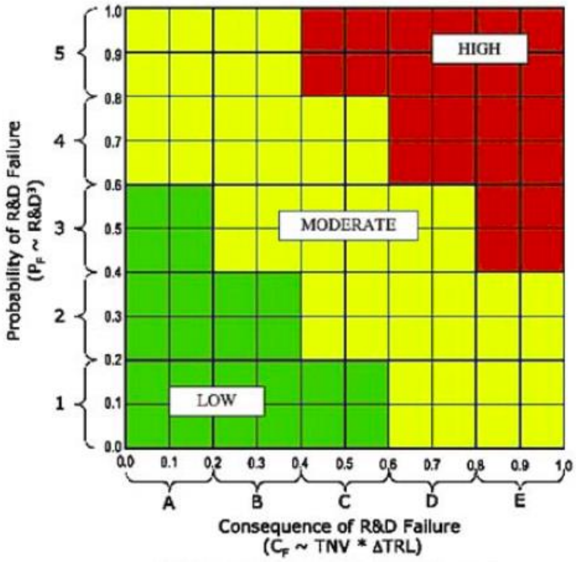


Figure 13: Mankins' risk assessment matrix with TRL, R&D3 and TNV dimensions added. [J. Mankins 2009]

To put the importance of successful technology and product development into perspective, Song, Song, & Parry [Song et al. 2010] show in their study that the failure of a venture's first product can increase the chance of overall failure for the venture drastically – for ventures where first products failed, the success rate (in terms of achieving self-defined goals) was less than 23%. For companies with successful first products launches, the success rate was 77%.

Technology is but one of the risks challenging the success of an entrepreneurial venture. If the technological basis for the venture resides in the lower left corner of the technology risk matrix, the main risks facing the venture are likely to come from other sources than technology (market, customer, legal issues etc.). In this case, the venture should allocate resources toward risk mitigation in other areas.

Often, software companies are described as *tech startups* as their products and services are reliant (high *TNV*) on software technology platforms. However, the maturity (*TRL*) of these platforms is often high and the degree of difficulty involved in developing them (*R&D3*) is limited. In contrast to this, many maritime suppliers are often dependent on elaborate and complex technologies featuring mechanical-, electronic- and software subsystems. These technologies are exceedingly difficult to develop and test, due to immense development costs, lack of infrastructure and tradition for testing new solutions. A good example is scrubber technology, which is one of many flue gas-cleaning solutions able to meet the current regulations facing the maritime branch (the shipowners). Despite now being a widely adopted solution, scrubbers faced major hurdles in the development from immature technology (invention) to a commercially viable and reliable solution (innovation). One important hurdle was the fact that the massive prototypes of the scrubber, weighing dozens of tonnes had to integrated and tested aboard vessels. The integration involved making extensive modifications to the ship's structure and even with the integration completed, the scrubber prototype could fail in a number of ways, during its test operations – which indeed it did. In other words, the degree of difficulty (*R&D3*) in developing the scrubber to a more mature state (*TRL*) is several orders of magnitude beyond the difficulties seen in maturing e.g. software technologies.

3.4.2 EMPIRICAL INSIGHTS: COMMERCIALISING THE SILP TECHNOLOGY FOR FLUE GAS CLEANING

To provide an empirical perspective on the theoretical discussions in the technology entrepreneurship research field an empirical study was initiated by the author. The study was conducted by two experienced entrepreneurs (studying engineering) with the author in a supporting role and it used a flexible research design [Robson 2011], in which the two entrepreneurs applied an auto-ethnographic method [Hayano 1982; Duncan 2004]. The entrepreneurs were tasked with commercialising a novel flue gas cleaning technology, which is based on a recently discovered *"ionic liquid",* which can be used in catalysing various chemical processes. The application of the *ionic liquid* in a porous filter is referred to as a *Supported Ionic Liquid Phase* (or SILP) technology. Read more about the project in the case box on page 43.

The commercialisation of the SILP technology was the sole task of the entrepreneurs for a four-month period. During this period, the entrepreneurs kept a diary [Badke-Schaub & Frankenberger 1999] in which notes were taken based on three questions:

1. *What was important today?*
2. *How did we approach the challenges?*
3. *What did we learn from it?*

These questions were designed to be as non-leading as possible (e.g. by not imposing categories of activities), while at the same time ensuring the capture of data relevant to cognitive strategies, dynamic responses to external factors and the role of knowledge.

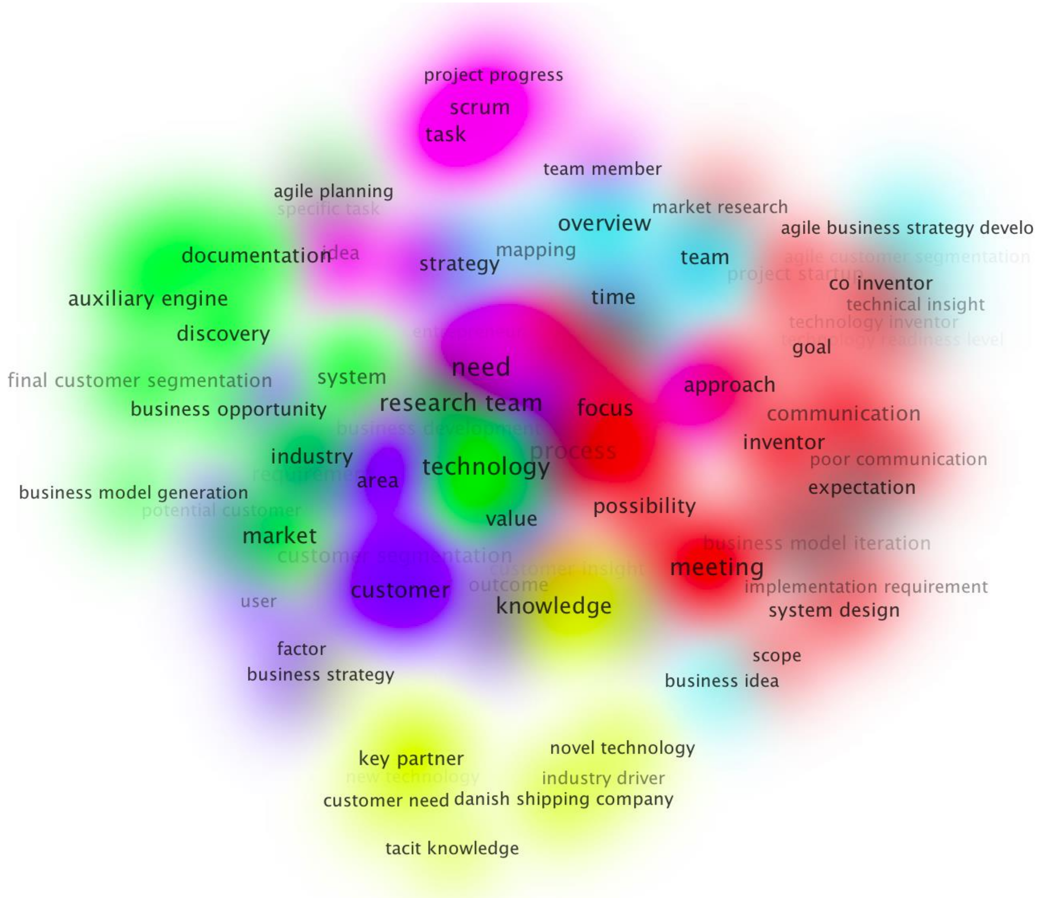


Figure 14: Clustering of themes from diary notes [Larsen & Rasmussen 2014]

The resulting diary notes were then analysed using various qualitative methods [Miles & Huberman 1984]. Grounded theory [Glaser & Strauss 1967; Charmaz 2006] was used to build a theoretical understanding of the contents of the diary notes. To support the clustering of topics and components of the data, the natural language data from the diary notes was processed using the visualisation tool VOS Viewer [Eck & Waltman 2011]. See an example of one of the clustering analyses in Figure 14. The results from the clustering of terms and concepts are presented in the section *Empirical insights from a technology entrepreneurship process.*

3.4.2.1 THE TECHNOLOGY

As mentioned, the SILP technology, developed at the chemistry department at the Technical University of Denmark, was the basis for the project. The use of *ionic liquid* essentially means that any surface wetted by the liquid will stay wet. The presence of the liquid film on the surface can increase the rate of several different chemical processes – including the absorption of NOx from the air passing the surface. Due to this, the SILP technology, where *ionic liquid* is applied to the internal surfaces of a porous filter can be used for absorbing NOx from flue gas. This is particularly interesting in the maritime branch, where shipowners are facing strict legislation on NOx contents in flue gas from the International Maritime Organisation (IMO).

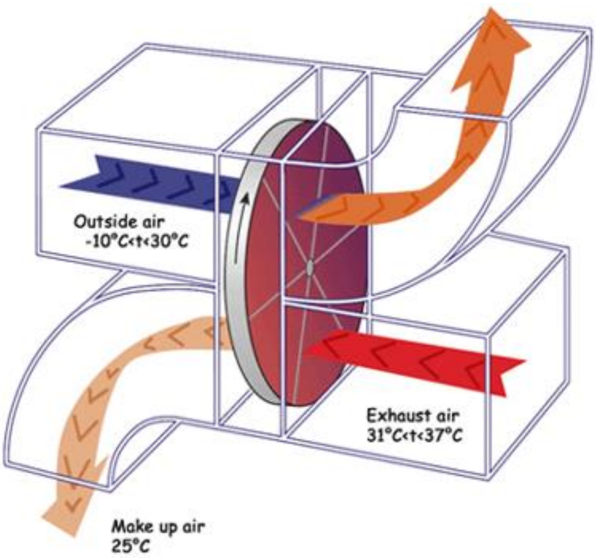


Figure 15: Representation of the rotating ionic liquid based filter and its operating principle. [Larsen & Rasmussen 2014]

At the initiation of the project, the filter had only been tested in a laboratory setting, corresponding to a technology readiness level (*TRL*) of 2-3. The SILP technology was central in making the overall system (the ship's exhaust) perform in accordance to new legislation. However, some alternatives – e.g. scrubbers, which have been mentioned – did already exist, meaning that the technology could conceivably be substituted. This gives the technology a *technology need value* (*TNV*) rating of 4-5. From a R&D degree of difficulty (*R&D3*) perspective, the technology was expected to be difficult to deal with, but not to the extent where scientific breakthroughs were needed for success to be achieved. This translates to an *R&D3* rating of 3. The corresponding placement of the SILP technology in the technology risk matrix is shown in Figure 16.

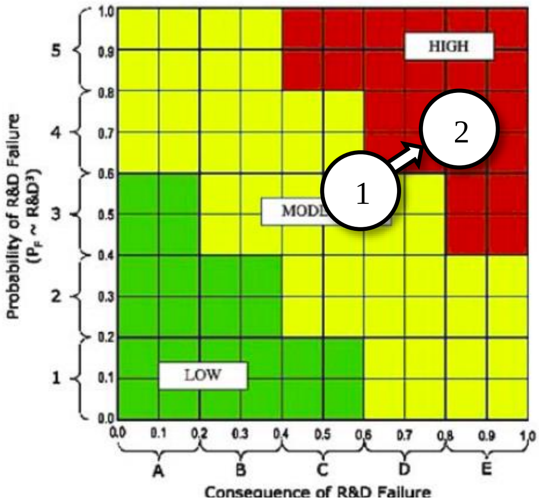


Figure 16: The placement of the SILP technology at different stages. [own, adapted from J. Mankins [2009]]

As will be mentioned below, the entrepreneurs working with the technology eventually realised that a number of technical factors severely challenged feasibility of the original formulation of the technology. This meant that the maturity of the technology was in reality lower and that the degree of difficulty in developing it would be higher than originally estimated.

3.4.2.2 IDENTIFICATION OF CENTRAL TOPICS FOR CHALLENGES

In the empirical study, the use of grounded theory allowed for the identification of several recurring topics for challenges facing the entrepreneurial venture. Read more about the exact methodology employed in this study in the chapter's methodology section. The case box below provides an excerpt from the technology implementation plan created by the entrepreneurs at the end of the project. The topics that emerged from the clustering analysis (see Figure 14, page 43) were:

- *Project initiation*
  This topic primarily had to do with the challenges experienced in enrolling and engaging the knowledge resources behind the technology – the inventors. The goals and expectations of the inventors of the technology turned out to be significantly different from those of the entrepreneur.

- *Context understanding*
  This topic contained a large number of challenges, which had to do with the challenge of identifying customers and other relevant stakeholders for the technology and aligning the activities of the team to the understanding.

- *Value creation*
  This topic covers a number of challenges that relate to the understanding of the technology and the potential value it can create. Also, this topic contains several challenges dealing with the development the technology to address identified customer needs.

- *Organising elements*

Here, the challenges include the creation of business models based on stakeholder insights and the validation of assumptions in the proposed business models. Also, the constant adaptation of the proposed business model was identified as a challenge.

- *Entire process*
  The final topic relates to all of the previous topics, as the challenges in managing the process were clear in all parts of the project work. Specifically, the task of structuring and prioritising tasks and getting a visual overview as the project unfolded and the prerequisites changed was seen as a significant challenge.

Case box: Concluding remarks in flue gas project
[Larsen & Rasmussen 2014]

As presented earlier, the maritime industry is very rigid, and nothing gets implemented without comprehensive testing and proving. Penetrating the main engine market will not only mean taking on competition with industry leaders like MAN Diesel & Turbo, but also require extensive funding.

The SILP technology is very immature and is still only being tested in the laboratory. To attract the huge capital investments needed to make it to market will require a full-scale test setup and this should be the main priority. Initiating cooperation with some of the Danish shipowners might very well be a good way to test a system design, but none of the shipowners contacted throughout the project seemed willing to invest capital in such a test setup.

Torm articulated that full-scale tests of other technologies had been conducted on vessels in their fleet at the expense of technology developers, and did not seem discouraged by the thought of testing new technologies again. Bornholmstrafikken [ferry company] *and their ferry M/S Hammerodde* [a ferry] *was also engaged in full scale testing of SCR, with poor results, but seemed very accommodating towards full scale testing of the SILP technology when asked, again at technology developer's expense.*

Assuming that the SILP technology is further developed in the lab to a stage where it can be utilised on a commercial scale, it is recommended to initiate a test phase on an auxiliary engine. Testing the technology on an AE will not only require less capital and expensive prototyping than a main engine test setup, but could also help in the process of market roll-out on the auxiliary engine arena. Competition is this market is less fierce, start-up less expensive and once proven durable, attracting investors to penetrate the main engine market will become more likely to happen.

Another approach would be to initiate contact to Wärtsilä once the technology is matured. Given that they have been losing market shares to MAN Diesel & Turbo, acquiring a technology able to compete with EGR would be of high value to them. But again, it all comes down to whether the technology proves applicable on full scale testing.

Despite not being direct analogies to the conceptual frameworks for entrepreneurship treated earlier [Bruyat & Julien 2001; Gartner 1985; Sarasvathy 2008], it is clear that the topics identified display many of the same characteristics. The next section will further investigate the familiarity between the empirical findings and the theoretical frameworks.

3.4.3 THE ROLES OF TECHNOLOGY IN ENTREPRENEURSHIP RESEARCH

So how does technology play a role when considering the central components of entrepreneurship - e*nvironment*, *process*, the *entrepreneur* (*"I"*) and the *opportunity* (*"NVC"*)? Using the empirical insights and a study of literature dealing with the topic, these concepts are now dealt with in turn.

3.4.3.1 ENVIRONMENT

The development of technology has historically been tightly coupled to environmental factors such as the presence of domain specific knowledge [Arthur 2009] and public policies. Denmark, as an example has a long tradition of supporting technological areas seen as conducive to financial, social and environmental goals. As a consequence, the *environment* in the form of public policies has facilitated the development of specific technologies such as wind turbines, whose current technological maturity can be attributed to massive public support for the technology in the 70s.

Also, as the types of industries present in a given region will differ, the same can be assumed to be the case for the presence of industry specific knowledge and competencies. As mentioned in chapter two, some people consider Scandinavia as a "Silicon Valley" for maritime technology. The presence of relevant knowledge, human resources and industries will most likely improve the likelihood of success for a given technological development. Conversely, the emergence of new technology (fuel cells, wind turbines, electric cars etc.), can drive the forming of knowledge clusters and public policies. This adds the notion of co-creation between *environment* and *technology* to the constructivist framework of Bruyat & Julien [Bruyat & Julien 2001].

In the case of the SILP technology project, the technology was suddenly rendered almost obsolete due to a postponement of the ratification of the legislation that dictates reductions of NOx in flue gas. This essentially meant that the impetus for adopting the technology had vanished and the technology was no longer urgently needed.

3.4.3.2 THE ENTREPRENEUR / THE "I"

The ability of the organisation to solve problems and create value based in a unique technological insights and knowledge, increases the degrees of freedom available in identifying and creating/identifying opportunities. This advantage over other entrants persists, even when the venture has been built, making it hard to replicate the particular means [S. A. Shane 2000] by which the entrepreneur and venture creates value. Park [Park 2005a] proposes a framework for understanding how the *technology* together with the *entrepreneur* and the *knowledge and experience of the firm* form a basis for innovation – see Figure 17.

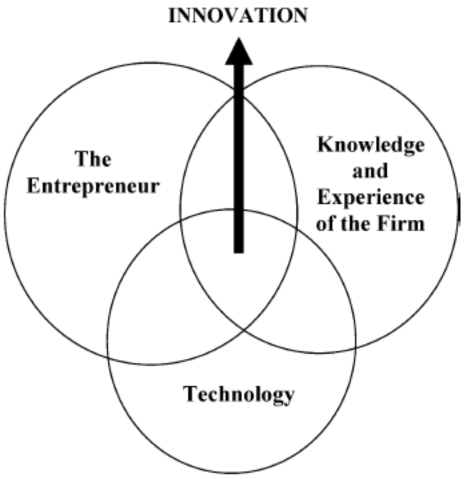


Figure 17: Park's model for the role of technology in innovation [Park 2005b]

In the empirical study, the entrepreneurs quickly realised the importance of the inventors in understanding the possibilities of the technology and its advantages over other solutions. Also, in developing the technology, the presence of relevant knowledge and experience was considered as an absolute necessity for a successful outcome.

3.4.3.3 OPPORTUNITY

The technology's virtues and advantages are crucial in understanding and creating opportunities. Existing systems are based on the limitations set by the technology available. New scientific discoveries [Arthur 2009; J. Schumpeter 1951] can disrupt the conventions of the system paving the way for *new value creation.*

In the ethnographic study of the SILP flue gas cleaning technology, the entrepreneurs quickly realised that the size of the particles in the flue gas coming from the ship's main engine was much larger than originally assumed. This led to the need for larger air channels in the central filter, which would allow the particles to pass through. This would in turn lead to a much smaller internal surface area for the filter meaning a greatly reduced cleaning capacity or a much larger filter. As the cleaning capacity was already at a minimum, the size increase was the only way forward. However, the spatial requirements for the solution (the room available on a ship) were very strict leaving no room for an increase in filter size and in essence; no immediate way forward for the technology in the maritime context.

3.4.3.4 PROCESS

Some technologies require only limited resources and time to reach the market. However, as established in the previous section, some technologies are massively difficult to commercialise requiring diverse competencies and large investments. From a process perspective, these types of technologies require very different strategies. The process dynamic that underlies Sarasvathy's *patchwork quilt* principle requires the solution and therefore the technology to be changed continuously until all relevant stakeholders' needs are addressed. This is easy to do for a software program, where some lines of code need to be changed, but very hard if one is dealing with a million dollar prototype of a *SILP*.

3.5 CONCLUSION: A LACK OF UNDERSTANDING OF PROCESS AND TECHNOLOGY IN ENTREPRENEURSHIP RESEARCH

This chapter has shown that despite being a well-established field, entrepreneurship research is still suffering from divergent theoretical understandings and a lack of common grounds. The *entrepreneur* and the *environment* for *entrepreneurship* has been the main focus for extant research efforts and the area of *entrepreneurial process* – the practical manifestation of *entrepreneurship* – is poorly understood.

Similarly, the role of technology in entrepreneurship (and entrepreneurship process) is poorly accounted for. Conversely, the area of design and innovation research, which has technology at its core, has yet to deal with the entrepreneurial context in any great extent.

These shortcomings in process and technology knowledge are a problem in terms of the stated ambition of providing support for technology entrepreneurship processes in maritime supplier companies.

Prominent researchers in the entrepreneurship field point to the lack of empirical insights as a reason for the poor understanding of processes. It is argued that this could very well be due to the lack of appropriate tools for doing research on entrepreneurship processes. Such tools are equally necessary in establishing an understanding of the role of technology in said processes.

3.6 REFLECTION ON CHAPTER CONCLUSIONS

The current discussions in entrepreneurship journals leaves little doubt that the lack of process knowledge and theory is considered problematic – especially in the eyes of certain prominent researchers in the field (e.g. [Neergaard & Ulhøi 2007; Moroz & Hindle 2012]).

Conversely, the identified lack of insights concerning the role of technology has not caused any mentionable expressions of concern. As already mentioned, this could be because the entrepreneurship field has traditionally more in common with management research than with design and innovation research and that the topic of technology is not a natural area of interest. It could also be because recent developments in manufacturing technology (e.g. 3D printing) has led to the conclusion that technology is no longer a barrier to entrepreneurs.

Another explanation could also be offered, which is more caustic to the goals of this thesis: That the technology belonging to the problematic corner of Mankins' risk matrix (Figure 13, page 42) simply does not belong to the domain of entrepreneurship. Perhaps such difficult technology is better handled in university research or other advanced research institutions.

Although this could perhaps be true for the extreme instances of technology (low TRL / high R&D3), this argument does not explain the general lack of research dealing with technology in the rest of Mankins' risk matrix. In this light, there is ample reason to proceed with the work to strengthen the understanding of technology's role in entrepreneurship.

CHAPTER 4:
THE REQUIREMENTS FOR ENTREPRENEURSHIP PROCESS RESEARCH TOOLS

RQ2.3:
How can entrepreneurship research be strengthened to better cater to the needs of technology venture processes?

In the previous chapter, the field of entrepreneurship research was explored, revealing two major shortcomings. The first was the lack of process theories backed by empirical evidence. This means that the current research effort is poorly founded in practice and – consequently – it is not very relevant to practitioners. One of the key reasons for this lack of process insights was identifies as a lack of appropriate research methods for gathering empirical evidence from entrepreneurial processes.

Another shortcoming is the lack of insights concerning technology and its role in entrepreneurial ventures. This weakness is particularly problematic to Danish maritime suppliers, as technology is and will remain a key component of their business.

This chapter will explore and enumerate the requirements for process research tools and propose a new way for capturing data from entrepreneurship processes and building theory. This new methodology will form the basis for the exploration of design- and innovation tools in the final chapter of the thesis.

However, even before the final chapter is reached, the area of design and innovation research will be drawn in, as many of its research tools will be used as a source of inspiration for the methodology developed.

4.1 CHAPTER RESEARCH DESIGN

This chapter's research methodology builds on many of same the sources and methods used in the previous chapter. However, when the chapter moves to conceptualising a new research tool, some of these tools are used for generative purposes rather than descriptive ones.

4.1.1 REQUIREMENTS FOR ENTREPRENEURSHIP PROCESS RESEARCH TOOLS

The theoretical frameworks used as a starting point for creating a requirement specification for a process research tool in the first part of this chapter are built on the same literature study described in chapter 3.

Similarly, the auto-ethnographic study introduced in chapter 3 is used to provide case-specific examples of the types of phenomenological dimensions, to be captured by the research tool proposed.

4.1.2 RESEARCH RIGOUR REQUIREMENTS

The theoretical underpinnings mentioned above enable the creation of a number of requirements, which are rooted in the (proposed) characteristics of the entrepreneurial phenomenon. Aside from these requirements, which are specific to the phenomenon, a number of requirements are listed, which relate to the rigour of this or any other research method – *validity*, *generalisability*, *reflexivity*, *bias issues etc.* These research caveats are well documented by scholars in a number of fields (e.g. [Malterud 2001; Huberman & Miles 2002; Robson 2011]).

4.1.3 EVALUATION OF EXISTING TOOLS

In the second section of the chapter, evaluating existing "real world" research methods, Robson's handbook [Robson 2011] and the methods listed therein are once again used. Robson's recommendations are used alongside recommendations coming from works in the qualitative entrepreneurship research method literature [Hindle 2004; Neergaard & Ulhøi 2007].

Finally, seeing a potential for finding inspiration in the process research methods seen in design- and innovation research, a number of these methods are introduced and scrutinised (e.g. [Badke-Schaub & Frankenberger 1999; Gero & McNeill 1998; Bucciarelli 1988; Hales 1986]).

4.2 SETTING REQUIREMENTS FOR ENTREPRENEURSHIP PROCESS RESEARCH TOOLS

As established in the previous chapter, several scholars [Neergaard & Ulhøi 2007; Moroz & Hindle 2012] have identified the lack of empirical research in the field as an antecedent of poor theoretical agreement in and practical application of entrepreneurship process research. To facilitate the proper application and use of research methods, this section revisits the current theoretical understanding of high tech entrepreneurship process as a phenomenon and based on this formulate a number of requirements to be met by current and future methods. The requirements derived from the phenomenon are then complemented by a number of well-established requirements pertaining to rigour in qualitative research efforts.

4.2.1 REQUIREMENTS DERIVED FROM ENTREPRENEURSHIP PROCESS RESEARCH

Below, the requirements emerging from the theoretical understanding of the entrepreneurial process and the empirical study of such a process will be listed, along with their background. As determined in chapter 3, the emergence of a new venture can be understood in terms of the interaction between four different conceptual entities; the *individual(s),* the *organisation,* the *process* and the *environment* [Gartner 1985]. In Gartner's view, none of these entities should be studied in isolation, meaning that the research method employed should capture data from each of them.

In Bruyat & Julien's work [Bruyat & Julien 2001], the important notion of dialogue and co-creation of the individual(s) *I* and the *New Value Creation* (NVC) is placed at the core of the entrepreneurship phenomenon. For a research tool to work properly, it seems critical that it captures data on this interaction.

Sarasvathy's [Sarasvathy 2008] angle on entrepreneurship deals with many of the same conceptual components as the scholars already mentioned, but she adopts a cognitive perspective on these, focusing on the cognitive strategies used by the entrepreneur in building a success.

4.2.1.1 INDIVIDUAL

To understand the process of venture creation, it is important to know the person / the people involved on a basic level. This knowledge of the individual could be personality traits (e.g. [Simon & Shrader 2012]), the background and training (e.g. [S. Shane 2000]) and cognitive strategies (e.g. [Dew et al. 2009]).

Another more ambiguous characteristic is the network of the entrepreneur; although clearly a component of the entrepreneur's environment, the relations between the entrepreneur and these external entities can be said to be a trait of the entrepreneur - – i.e. Sarasvathy's *"Whom do I know"*.

As established by [Bruyat & Julien 2001], the *Individual* will itself be affected by the processes he/she goes through. Therefore, the ability to capture the changes in characteristics of the entrepreneur is also valuable.

Finally, the auto-ethnographic study described in the last chapter revealed a need for documenting and understanding the motivation and goal of the different team members. In that case, at least, these factors were found to greatly influence the venture's development.

The resulting requirements for an entrepreneurship process research tool are:

R1.1	***Capture information on the individual's traits, motivation, goals and cognitive propensities.***	*Data such as experience with entrepreneurship, risk propensity, knowledge of relevant areas etc.*
R1.2	***Capture changes over time in the former***	*Maintaining a consistent format, which allows for direct comparison of data gathered at different times.*

4.2.1.2 ENVIRONMENT

Many studies have shown that the supporting environment (e.g. [Di Gregorio & Shane 2003; Gartner 1985]) for entrepreneurship is of crucial importance to the success of a startup. The components of this environment include availability of funding (e.g. [Sørheim et al. 2011]), knowledge/competencies (e.g. [Sullivan & Marvel 2011]) and relevant infrastructure such as distributors, technological platforms, policies etc.

For a research tool to work, it must capture the environmental characteristics relevant to the venture. In Bruyat & Julien's [Bruyat & Julien 2001] model for venture creation, the *environment* affects the *process*, but the opposite is also true – albeit in a less direct and comprehensive manner (few startups have changed government policy singlehandedly). It is therefore relevant to capture data on the *environment* for the venture.

The resulting requirements for an entrepreneurship process research tool are:

R2.1	***Capture data on environmental characteristics.***	*Such as availability of funding, availability of relevant knowledge/competencies, infrastructure, policies etc.*
R2.2	***Capture changes over time in the former.***	*Maintaining a consistent format, which allows for direct comparison of data gathered at different times.*

4.2.1.3 ORGANISATION

The type of organisation being created (service, manufacturing, wholesale, retail etc.) is an important dimension in understanding the phenomenon and the differences between instances of entrepreneurship activity. In Sarasvathy and Bruyat's views, the characteristics of the organisation are likely to change over time and converge toward a final solution (or fail). In this perspective, it is not sensible to characterise the organisation at project initiation – or rather, the researcher should not assume that this initial notion of the organisation will be constant as the process unfolds. Osterwalder's framework [Osterwalder et al. 2005] for characterising a business model – the *business model canvas* - provides a useful "snapshot" of the workings of the organisation. Such a snapshot enables the comparison of different cases and – if described for the same project at different times – it provides a good platform for understanding the changes in a project over time.

The resulting requirements:

R3.1	***Capture data on organisational characteristics***	*Such as sector and business model.*
R3.2	***Capture changes over time in the former***	*Maintaining a consistent format, which allows for direct comparison of data gathered at different times. E.g. the business model canvas.*

4.2.1.4 OPPORTUNITY AND NEW VALUE CREATION

The very core of entrepreneurship is the creation of new value based on an opportunity identified by the entrepreneur(s) [J. A. J. Schumpeter 1951]. Regardless of whether one thinks of this opportunity as being inexorably connected to the entrepreneur (the "*I")* in a constructionist sense, the ability to track and understand the opportunity and its relation to the emerging business is of extremely valuable.

The actions taken by entrepreneurs in pursuing opportunities and building products and services to exploit them – the *New Value Creation* – is also of great theoretical significance. The research tools used should be able to establish relations between the *opportunity* and the *NVC*.

The constructionist perspective assumes that the opportunity is a dynamic concept [Garud et al. 2010; Bruyat & Julien 2001], which means that an initial notion of the opportunity will not suffice in understanding the emergence process. Opportunities should be described over time.

R4.1	***Track and document the opportunity.***	*Including data on the entrepreneur's strategy for identifying/creating the opportunity.*
R4.2	***Capture relations between opportunity and solutions.***	*Document which solutions are created to exploit opportunity and how solutions affect the opportunity.*
R4.3	***Capture changes in opportunity understanding over time.***	*Maintaining a consistent format, which allows for direct comparison of data gathered at different times.*

4.2.1.5 COGNITIVE STRATEGIES

Sarasvathy's think-aloud studies [Sarasvathy 2008] put focus on the importance of the entrepreneurs' cognitive strategies. As the title of Gartner's paper states *"'Who is an Entrepreneur?' Is the Wrong Question."* [Gartner 1988], meaning that the actions (process) of the entrepreneur are as important as his/her traits. Many actions can be observed, but gaining an understanding of the underlying cognitive processes can be a major challenge, as such insights cannot be extracted without the active participation (response) of the entrepreneur. Still, the cognitive processes are of great interest in the attempt to understand the overall process of entrepreneurship.

R5.1	***Capture data on the cognitive strategies of the entrepreneur.***	*Document how entrepreneurs cognitively approach address problems and emerging opportunities.*

4.2.1.6 PROCESS

As stated by Bygrave in [Neergaard & Ulhøi 2007] and by [Moroz & Hindle 2012], one of the main challenges in entrepreneurship process research is the lack of appropriate tools and the incorrect use of existing tools.

Moroz & Hindle posit that any entrepreneurial study should help in understanding the following:

> *1. How change is created (the transformation of inputs to outputs);*
> *2. The ontology of "becoming" that is associated with progressive individual and social change that takes place as a result of the transformational process.*

Based on the first point, it would be practical if the research tool employed enables the identification of the *input* state, the transformation process and the resulting *output* state (see Figure 18).

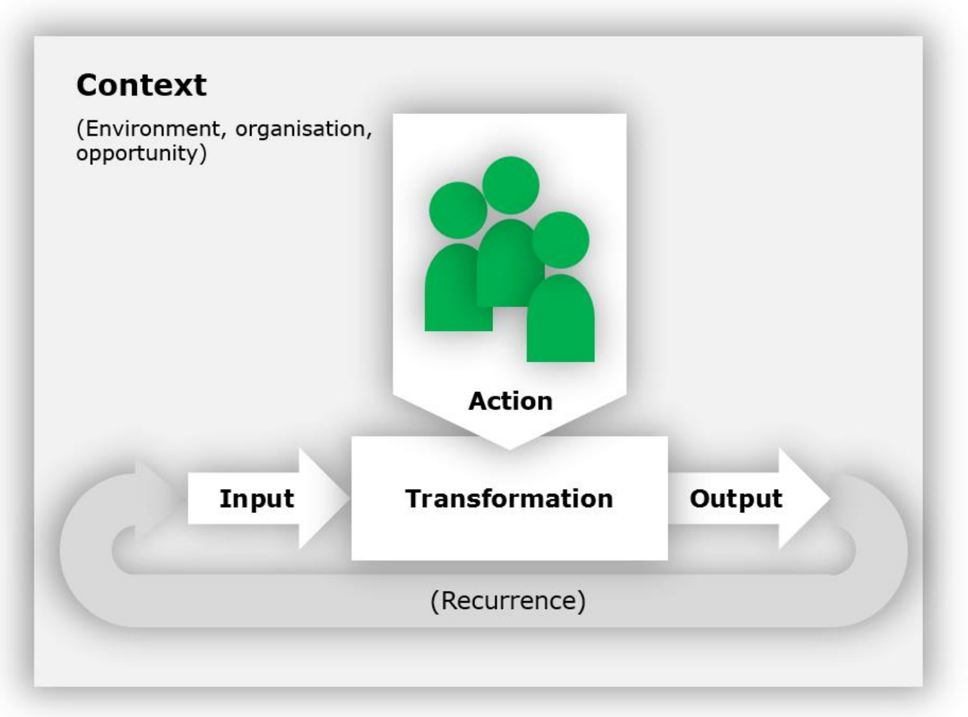


Figure 18: Inputs transformed by the actions of the entrepreneur(s) into outputs. [own]

A clear understanding of inputs would enable the identification of similar input states in the same or other processes. This grouping of input states would enable a comparison of how various actions by the entrepreneurs transform the input to different outputs.
As Moroz & Hindle also point out (second point above), the *ontology of becoming* needs to be understood. If inputs and outputs are well described in terms of the factors described above (*environment, organisation, opportunity etc.*), the researcher can start to evaluate how the progressive actions of the entrepreneur shape the surroundings of the venture.

The resulting requirements:

R6.1	***Structure the understanding of the process in terms of transformation of inputs into outputs.***	*The actions of the entrepreneur in creating the transformation is a crucial dimension.*
R6.2	***Document the changes to individual and social dimensions brought on by the transformational process.***	*Illustrate the emergence of the firm (the entrepreneur) and its market.*

Moroz & Hindle also summarise the current perspectives on entrepreneurship in a taxonomy for process models (see
Table 3, page 39).

From this taxonomy, it is clear that researchers have varying views on how the process of entrepreneurship is best understood: One view of the process is a *stage model* with pre-defined stages of maturity, allowing for iterative features between the stages. This process view is similar to the *quantification sequence* models, which deal with the process on a very general level (e.g. Gartner's *Up and Running*, *Still Going* and *Given Up* [Carter et al. 1996]). Another view looks at the *process dynamics* for understanding the immediate actions of the entrepreneur that does not necessarily account for the overall, long-term themes of the process. Finally, the process can also be seen from a content perspective without looking at the time dimension. In this *static framework*, the composition of process components is in focus, rather than their causal links and timing.

Without making any pre-emptive conclusions on whether one view is more valid than the other one can assert that temporal data cannot be derived from a *static framework* (see Figure 19). Similarly, process dynamics data cannot be derived from a *stage model* or from *quantification sequences*. These derivations fail because new data needs to be created for them to work. It is, however, possible to derive *stage models* and *static frameworks* from process dynamics data. This is because the data from the *process dynamics* data can be clustered, averaged out and aggregated to create these less complex interpretations.

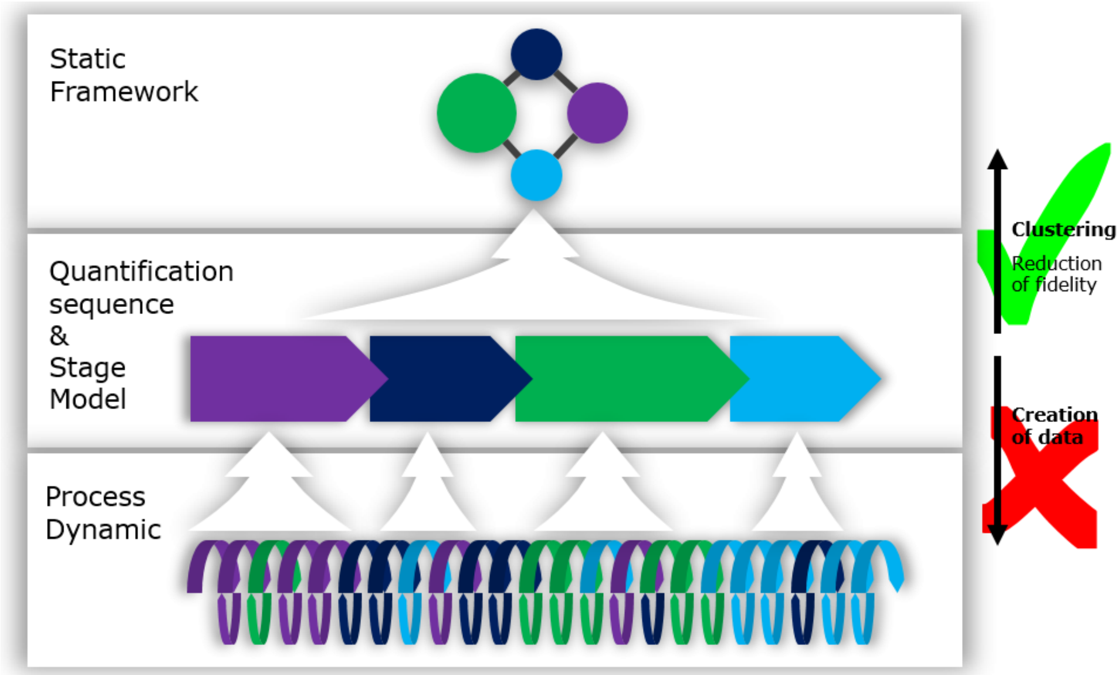


Figure 19: Derivation of simpler models from process dynamic data. [own]

To ensure an ability to support analyses based on all types described in Moroz & Hindle's taxonomy, the research method should support capturing of data at the *process dynamics* level.

R6.3	***Capture process dynamics data.***	*With the option to derive stage models and static frameworks from data.*

In studying design processes, [Gero & McNeill 1998] found that the short duration (around 10 seconds) activities of the designer called *micro strategies* were crucial for understanding the work of the designer. Furthermore, longer duration chunks (2-5 minutes) of activities called *macro strategies* were very found to be very useful in creating a context for the *micro strategies*. As stated in chapter 3, several parallels can be drawn between the work of the designer and the entrepreneur. Therefore, it is proposed that activities on a *micro strategy* level could be of value to entrepreneurship process research. Especially if the context for the strategy is determined – e.g. in the form of *macro strategies*.

R6.4	***Capture activities of durations down to <10 seconds (no upper limit).***	*Capture the very short-term strategies of the entrepreneur.*

R6.5	***Capture context for activities.***	*To ensure a good understanding of short duration activities.*

4.2.1.7 FOLLOWING THE ENTREPRENEUR AND AVOIDING OBSTRUCTION

Despite differences in opinion on central components of the phenomenon, entrepreneurship researchers generally agree on the following; that opportunism, unpredictability, constant changes in direction and sudden emergence and death are all part entrepreneurship's nature [Sarasvathy 2008; Baker & Nelson 2005; J. A. J. Schumpeter 1951]. This chaotic nature poses a challenge to any research tool hoping to follow the process and capture data – especially in the early stages, where the entrepreneurs might be embedded in other organisations (day jobs) and working only on the venture, when time is available or when opportunities arise.

Research tools need to be able to capture data from suddenly emerging projects and capture data when the entrepreneur is active on the project – be it on the bus, at the day job or in an incubator.

Entrepreneurs are building something from nothing, meaning that they are faced with constant and extreme resource scarcity [Baker & Nelson 2005]. Although not always the case, it is safe to assume that entrepreneurs at least try to direct their resources (time, capital etc.) toward the tasks that promise to yield the biggest commercial results. Taking part in a research project is not necessarily in alignment with this overall strategy. Good qualitative research rarely provides results on the shorter term, which is acceptable in larger companies, where future projects could conceivably benefit from the research efforts. In the entrepreneurial context, there is no future project, as each venture is most likely a one-off. As mentioned above, the venture is also likely to change its priorities rapidly, which can suddenly render a statically framed research project obsolete or irrelevant. Instead of providing a benefit for the venture, research projects are therefore at risk of developing into liabilities, obstructing the natural progression and development of the venture.
These considerations lead to the following requirements:

R7.1	***Capture data at unpredictable locations and times.***	*Entrepreneurship processes unfold when there is time or reason for initiating them.*
R7.2	***Unobtrusive to the process observed.***	*Entrepreneurs have very limited resources and a study must not strain these.*
R7.3	***Create value for entrepreneur.***	*Findings and conclusions emerging on the longer term will be less relevant to the project at hand.*

4.2.2 REQUIREMENTS DERIVED FROM TECHNOLOGY DEVELOPMENT RESEARCH

In this section, the requirements for capturing and interpreting data relating to technology and its role in the venture are determined.

4.2.2.1 TECHNOLOGICAL RISK

[J. Mankins 2009] has created a framework for understanding technological risk in R&D projects. Mankins introduces three parameters – the *technology readiness level* (TRL) the *technology need value* (TNV) and the *R&D degree of difficulty* (R&D3) – which together form a sufficient basis for understanding technological risk. To understand the role of technology in an entrepreneurial venture, it seems feasible to track these parameters and their change over time.

However, if technology is not a big unknown in the emerging venture or if the consequence of failed technology development is limited, there is little need for an analysis of the role of technology. In other words, before diving into a study of technological risk in the entrepreneurial process, one should determine if the venture is actually dependent on advanced technology.

The resulting requirements:

R8.1	***Determine whether a given venture is dependent on technology or not.***	*Using the technology need value (TNV) parameter or similar.*
R8.2	***Determine technological risk.***	*Using technology readiness level (TRL) and R&D degree of difficulty (R&D3)*

4.2.2.2 THE INFLUENCE OF TECHNOLOGY

In the previous chapter's section 3.4.3, a number of potential roles of technology in the entrepreneurship phenomenon were discussed. One example of this interaction between the *entrepreneur*, the *organisation* and the *technology* is [Park 2005a]'s model for innovation (see Figure 17). This model and the research upon which it builds indicate a great potential for deeper scrutiny of the role of technology in relation to the well-established concepts of entrepreneurship research.

The empirical (auto-ethnographic) study presented in chapter 3 also documented a number of situations, where key concepts in entrepreneurship theory such as *opportunity* were directly affected by technological factors. Indeed, the entrepreneurs in the study explicitly called for a better understanding of how technology is developed to provide the value for stakeholders. The resulting requirements:

R9.3	***Capture relations between technology and conceptual components of entrepreneurship theory.***	*Relate technological concepts to entrepreneurship concepts such as opportunity, organisation, "I" etc.*

4.2.3 REQUIREMENTS DERIVED FROM QUALITATIVE RESEARCH METHODOLOGY

Regardless of phenomenological setting (e.g. entrepreneurship), a number of standard measures exist for evaluating the validity of a study and its epistemological underpinnings. In a *positivist* research paradigm (typically *quantitative* in nature), measures such as *sample validity*, *statistical significance* and *external validity* are often used to validate conclusions.

In the *critical realism* paradigm, these measures become exceedingly difficult to describe and interpret as the object of the study includes *qualitative* (i.e. subjective) elements, which cannot be measured independently and consistently. Nevertheless, several scholars have proposed a set of categories for evaluating the validity of qualitative studies [Malterud 2001; Robson 2011; Miles & Huberman 1994]. These categories should normally be evaluated based on the specific study as the researcher's use of the tool can affect validity as much as the tool itself. However, the tool itself can still be more or less appropriate for supporting valid conclusions. A discussion of the tool in terms of the categories is therefore relevant. Miles & Huberman [Huberman & Miles 2002] provide a number of widely adopted categories for validity in qualitative studies. Similarly, Robson provides an exhaustive list of so-called *"threats to validity"* in *flexible research designs*.

Finally, design researchers such as Cash et al [Cash et al. 2010], provide a number of useful points on ensuring rigorous research. All of these contributions will be discussed below and compiled into a list of relevant requirements for entrepreneurship process research tools.

4.2.3.1 DESCRIPTIVE VALIDITY (ROBSON: "DESCRIPTION")

The detail and quality of the data one collects and uses to describe the phenomenon is of crucial importance. Robson recommends using tape recordings or video whenever possible or to take detailed notes when observing [Robson 2011]. If a good description is not available, subsequent steps will be negatively affected.

Any description has a theoretical background [Huberman & Miles 2002], but in descriptive validity, the underlying theories are not questioned (this is left for the *theoretical validity* below). Rather in *descriptive validity* relates to problems involved in obtaining data relevant to the theory used.

The resulting requirements:

R10.1	***Ensure, consistent accurate and detailed data capture.***	*Insensitive to researcher loss of concentration or absence.*
R10.2	***Capture data relevant and sufficient for supporting the underlying theory.***	*Assuming that an explicitly stated theoretical basis exists for the study. Otherwise, theory is in the form of (the researcher's) common sense.*

4.2.3.2 INTERPRETATIVE VALIDITY (ROBSON: "INTERPRETATION")

Interpretations of a phenomenon, which are based on an imposed framework – even if this framework forms the initial basis for *description* (see previous section) – can pose a threat to the validity of the study's conclusion. In a *flexible research design*, the theoretical understanding should emerge from the observations made and data collected, not the other way around [Robson 2011].

The way in which interpretations are made and conclusions drawn should be explicitly stated. Any assumptions on self-evident interpretations should be challenged and the steps taken in reaching a conclusion should be made clear to reviewers of the research.

Miles & Huberman discuss *emic* and *etic* interpretations of an observed phenomenon [Huberman & Miles 2002]. The *etic* interpretation is the researchers' understanding of what is happening in a given situation. The *emic* alternative refers to the observed participants' interpretation of the phenomenon. In a *critical realist* perspective, the ideal interpretation is the one, which is seen from the participants' perspective. One way of doing this is to do *member checking* where interpretations are validated post hoc by the participants in the study [Robson 2011].

The resulting requirements:

R11.1	***Enable efficient and consistent interpretation of data gathered.***	*Helping the researcher state assumptions and enabling transparency for reviewers and future research efforts.*
R11.2	***Enable clear communication of interpretative steps.***	*For reviewers, future research and for validation with participants.*

4.2.3.3 THEORETICAL VALIDITY (ROBSON: "THEORY")

Theoretical validity refers to the *"…the legitimacy of the application of a given concept or theory to established facts, or indeed whether any agreement can be reached about what the facts are"* [Huberman & Miles 2002]. The description and interpretation of a phenomenon is rooted in the assumption that a theoretical perspective is appropriate. Theoretical validity is challenged if there is disagreement about the appropriateness of the underlying theory, its concepts and the relations between these. The legitimacy of mapping a given fact (observed in the real world) to a theoretical concept is often termed *construct validity.* The appropriateness of the proposed relations (causal, spatial etc.) between theoretical concepts is known as *critical validity.*

The resulting requirements:

R12.1	***The theoretical underpinnings of the study should be explicitly stated.***	*To evaluate the appropriateness of the theory to the studied phenomenon.*
R12.2	***Disagreements on theoretical perspectives should be made explicit.***	*Explicate the limitations in the theoretical account and the construct- and critical validity.*

4.2.3.4 GENERALISABILITY

Positivist research paradigms are centred on the statistical inference of results from a sample to a general population. This is made possible by the fact that variables in *experiments* can be seen as objective and can be transferred to other parts of the population [Robson 2011]. However, in *qualitative* (*realist*) research paradigms, the documented concepts or variables are usually subjective making it exceedingly difficult to draw any meaningful statistical inferences. Instead, *qualitative* research relies on the formulation of theories, which can be used to understand the behaviour in other parts of the population. The ability of a theory to depict behaviour and characteristics in other parts of a. population is known as *generalisability* [Huberman & Miles 2002]. The extension of theory to other groups in the same community and organisation is referred to as *internal generalisability.* The ability to extend the theory to describe different communities and other parts of the general population is referred to as the *external generalisability.*

In *positivist* research, the notion of a *randomised controlled trial* is the gold standard enabling statistical inferences. In such a study, the sample is selected across the population and the number of respondents (if dealing with human studies) is large enough to statistically justify generalisations to the entire population. In qualitative research, the sample size is typically much smaller – partly because the effort spent on each respondent is far larger than the in quantitative research (e.g. in ethnographic studies or interviews). For this reason, qualitative researchers cannot rely on *randomised sampling*, as a statistically significant sample is unobtainable. Instead, other sampling strategies are used [Huberman & Miles 2002; Robson 2011], such as *theoretical sampling.* This refers to the fact that the chosen sample is well understood in terms of the theory used to describe and interpret it. Often so-called *purposeful sampling* is used. This sampling strategy simply entails picking a sample based on who might benefit from the research – e.g. a company study.

Robson proposes a way to test the validity of generalisations, which is to focus on negative-cases – i.e. cases where the theoretical predictions seem to predict. This would enable the improvement of the theory and/or the identification of problems in the *descriptive validity*, making it a worthwhile task.

The resulting requirements:

R13.1	***The sample should be described in terms of the theoretical basis for the study.***	*To ensure a basis for extending interpretations to other samples using theory.*
R13.2	***Enable estimation and validation of internal and external generalisation.***	*Through evaluation of theory in relation to other samples (e.g. negative cases).*

4.2.3.5 BIAS (ROBSON)

In *critical realism*, the presence of bias in the results is a fact of life. As already discussed, a non-random sampling strategy will affect (bias) the observed characteristics and behaviour. However, other biasing issues should be accounted for and, if possible, mitigated when conducting research on entrepreneurial processes.

Descriptive- and *interpretive validity* deal with the epistemological issues involved in doing real world research. Using specific research tools can directly affect these categories of validity as no single instrument can account for all dimensions of the phenomenon – especially in the qualitative paradigm where subjective features are described. Ethnographers would argue that their immersive strategy, where a group of people is followed over an extended period, is the method most likely to yield a precise rendition of reality. However, as argued by [Huberman & Miles 2002], the researcher him-/herself is the instrument. In a *relativist* ontology [Robson 2011], the researcher (as instrument) is inseparable from the observed phenomenon and the description is very much dependant on his/her perspectives and background. As such, the researcher is biasing the result. In *critical*- or *subtle realism* a less integrated perspective is taken, where the reality of the phenomenon exists separately from the researcher. Instead, these *realist* perspectives call for a critical reflection on the role of the researcher and the ways in which the researcher as instrument or the researcher's instrument can bias the description.

The resulting requirements:

R14.1	***Account for potential bias issues in research method.***	*Including highlighting of limitations in data gathered.*

4.2.3.6 TRIANGULATION

One way to mitigate a number of validity issues is to triangulate using several sources [Robson 2011]. The idea is that arriving at the same conclusion by using different sources of data or different lines of reasoning strengthens the rigour of the research. Robson deals with four types of triangulation; *Data triangulation,* which entails using different sources of data to support the description and interpretation. The second type is *observer triangulation,* where different observers look at the same phenomenon. The third is *methodological triangulation*, where similar data is gathered using different methodologies. Lastly, there is *theoretical triangulation,* where data is gathered, described and interpreted using a variety of theories.

The resulting requirements:

R15.1	***Use triangulation to strengthen rigour.***	*Data-, observer-, methodological- and/or theoretical triangulation.*

4.3 CONCLUSION: A REQUIREMENT SPECIFICATION FOR TECHNOLOGY ENTREPRENEURSHIP PROCESS RESEARCH TOOLS

In Table 6, the full list of requirements for entrepreneurship process research tool is shown. These tables will serve as a basis for the evaluation of existing research tools and the development of a new research tool in the remaining sections of this chapter.

Requirement derived from entrepreneurship process theory

Individual	***R1.1***	***Capture information on the individual's traits, motivation, goals and cognitive propensities.***	*Data such as experience with entrepreneurship, risk propensity, knowledge of relevant areas etc.*
	R1.2	***Capture changes over time in the former.***	*Maintaining a consistent format, which allows for direct comparison of data gathered at different times.*
Environment	***R2.1***	***Capture data on environmental characteristics.***	*such as availability of funding, relevant knowledge/competencies, infrastructure, policies etc.*
	R2.2	***Capture changes over time in the former.***	*Maintaining a consistent format, which allows for direct comparison of data gathered at different times.*
Organisation	***R3.1***	***Capture data on organisational characteristics.***	*Such as sector and business model.*
	R3.2	***Capture changes over time in the former.***	*Maintaining a consistent format, which allows for direct comparison of data gathered at different times. E.g. the business model canvas.*
Opportunity	***R4.1***	***Track and document the opportunity.***	*Including data on the entrepreneur's strategy for identifying/creating the opportunity.*
	R4.2	***Capture relations between opportunity and solutions.***	*Document which solutions are created to exploit opportunity and how solutions affect the opportunity.*
	R4.3	***Capture changes in opportunity understanding over time.***	*Maintaining a consistent format, which allows for direct comparison of data gathered at different times.*
Cognitive strategies	***R5.1***	***Capture data on the cognitive strategies of the entrepreneur.***	*Document how entrepreneurs cognitively approach address problems and emerging opportunities.*
Entrepreneurship process	***R6.1***	***Structure the understanding of the process in terms of transformation of inputs into outputs.***	*The actions of the entrepreneur in creating the transformation is a crucial dimension.*
	R6.2	***Document the changes to individual and social dimensions brought on by the transformational process.***	*Illustrate the emergence of the firm (the entrepreneur) and its market.*
	R6.3	***Capture process dynamics data.***	*With the option to derive stage models and static frameworks from data.*
	R6.4	***Capture activities of durations down to <10 seconds (no upper limit).***	*Capture the very short-term strategies of the entrepreneur.*
	R6.5	***Capture context for activities.***	*To ensure a good understanding of short duration activities.*
Following the entrepreneur and avoiding obstruction	***R7.1***	***Capture data at unpredictable locations and times.***	*Entrepreneurship processes unfold when there is time or reason for initiating them.*
	R7.2	***Unobtrusive to the process observed.***	*Entrepreneurs have very limited resources and a study must not strain these.*
	R7.3	***Create value for entrepreneur.***	*Findings and conclusions emerging on the longer term will be less relevant to the project at hand.*

Requirements derived from technology development research

Technological risk	***R8.1***	***Determine whether a given venture is dependent on technology or not.***	*Using the technology need value (TNV) parameter or similar.*
	R8.2	***Determine technological risk.***	*Using technology readiness level (TRL) and R&D degree of difficulty (R&D3)*
Influence of technology	***R9.3***	***Capture relations between technology and conceptual components of entrepreneurship theory.***	*Relate technological concepts to entrepreneurship concepts such as opportunity, organisation, "I" etc.*

Requirements derived from qualitative research methodology

Descriptive validity	***R10.1***	***Ensure consistent accurate and detailed data capture.***	*Insensitive to researcher loss of concentration or absence.*
	R10.2	***Capture data relevant and sufficient for supporting the underlying theory.***	*Assuming that an explicitly stated theoretical basis exists for the study. Otherwise, theory is in the form of (the researcher's) common sense.*
Interpretative validity	***R11.1***	***Enable efficient and consistent interpretation of data gathered.***	*Helping the researcher state assumptions and enabling transparency for reviewers and future research efforts.*
	R11.2	***Enable clear communication of interpretative steps.***	*For reviewers, future research and for validation with participants.*
Theoretical validity	***R12.1***	***The theoretical underpinnings of the study should be explicitly stated.***	*To evaluate the appropriateness of the theory to the studied phenomenon.*
	R12.2	***Disagreements on theoretical perspectives should be made explicit.***	*Explicate the limitations in the theoretical account and the construct- and critical validity.*
Generalisabilit y	***R13.1***	***The sample should be described in terms of the theoretical basis for the study.***	*To ensure a basis for extending interpretations to other samples using theory.*
	R13.2	***Enable estimation and validation of internal and external generalisation.***	*Through evaluation of theory in relation to other samples (e.g. negative cases).*
Bias	***R14.1***	***Account for potential bias issues in research method.***	*Including highlighting of limitations in data gathered.*
Triangulation	***R15.1***	***Use triangulation to strengthen rigour.***	*Data-, observer-, methodological- and/or theoretical triangulation.*
	R15.2	***Disagreements on theoretical perspectives should be made explicit.***	*Explicate the limitations in the theoretical account and the construct- and critical validity.*

Table 6: A requirement specification for entrepreneurship process research tools

4.4 EVALUATION OF EXISTING PROCESS RESEARCH TOOLS AGAINST REQUIREMENTS

In this section, the requirement specification formulated in the beginning of the chapter will be used as a basis for evaluating the appropriateness of six real world research methods, which have been extensively investigated. Table 7 provides an overall evaluation of all the tools presented in terms of the requirement specification in Table 6

The methods have been selected by using Robson's overview of research methods as a starting point [Robson 2011]. Design- and innovation research has also been used as a source of inspiration, providing additional methods and useful perspectives on already selected methods [Badke-Schaub & Frankenberger 1999; Gero & McNeill 1998; Verganti 2008; Cash et al. 2011]. Most of the methods presented (e.g. *participant observation*) are a simplified account of what is in reality a huge number of sub-methods and variations, which will undoubtedly have different characteristics than the generic versions of the methods. Instead of trying to cover the huge diversity within each method, the following sections will present the typical instantiations of methods. Arguably, versions of the methods presented can be found that will perform better than the generic account, in terms of the requirements listed above. However, the purpose of this section is to elucidate the general advantages and shortcomings of the methods, in order to support the development of a better method.

			Interviews and surveys	Participant observation	Structured Observation	Document analysis	Automated techniques
Requirement derived from entrepreneurship process theory							
Individual	**1.1**	*Capture the individual's traits and cognitive propensities.*	x	x	x		x
	1.2	*Capture changes over time in the former.*	x	x	x		x
Environment	**2.1**	*Capture data on environmental characteristics.*	x	x	x	x	x
	2.2	*Capture changes over time in the former.*	x	x	x	x	x
Organisation	**3.1**	*Capture data on organisational characteristics.*	x	x	x	x	x
	3.2	*Capture changes over time in the former.*	x	x	x	x	x
Opportunity	**4.1**	*Track and document the opportunity.*	x	x	x	x	x
	4.2	*Capture relations between opportunity and solutions.*	x	x	x	(x)	x
	4.3	*Capture changes in opportunity understanding over time.*	x	x	x	(x)	x
Cognitive strategies	**5.1**	*Capture data on the cognitive strategies of the entrepreneur.*	(x)	x	x		x
Entrepreneurship process	**6.1**	*Describe process in terms of transformation of inputs into outputs.*	x		x	(x)	x
	6.2	*Document the changes to individual and social dimensions.*	x	x	(x)	(x)	(x)
	6.3	*Capture process dynamics data.*		(x)	x		x
	6.4	*Capture activity durations down to <10 seconds (no upper limit).*		(x)	(x)		x
	6.5	*Capture context for activities.*	x	x	(x)	(x)	(x)
Following the entrepreneur and avoiding obstruction	**7.1**	*Capture data at unpredictable locations and times.*				x	x
	7.2	*Unobtrusive to the process observed.*			x	x	x
	7.3	*Create value for entrepreneur.*					
Requirements derived from technology development research							
Technological risk	**8.1**	*Determine if given venture is dependent on technology or not.*	x	x	x	(x)	x
	8.2	*Determine technological risk.*	x	x	x	(x)	x
Influence of tech	**9.3**	*Capture relations between technology and conceptual components.*	x	x	x	(x)	x
Requirements derived from qualitative research methodology							
Descriptive validity	**10.1**	*Ensure, consistent accurate and detailed data capture.*	x	(x)	x		x
	10.2	*Capture data relevant and sufficient for supporting theory.*	x	(x)	x	x	x
Interpretative validity	**11.1**	*Enable efficient and consistent interpretation of data gathered.*	x	(x)	x	(x)	x
	11.2	*Enable clear communication of interpretative steps.*	x	x	x	(x)	x
Theoretical validity	**12.1**	*Explicitly state the theoretical underpinnings of the study.*	x	x	x	(x)	x
	12.2	*Make disagreements on theoretical perspectives explicit.*	x	x	x	x	x
Generalisability	**13.1**	*Describe sample in terms of the theoretical basis for the study.*	x	x	x	(x)	x
	13.2	*Enable evaluation of internal and external generalisation.*	x	(x)	x	x	x
Bias	**14.1**	*Account for potential bias issues in research method.*	x	(x)	x	x	x
Triangulation	**15.1**	*Use triangulation to strengthen rigour.*	(x)	(x)	(x)	(x)	x

Table 7: Evaluation of research methods against requirement specification.

In the sections below, it will become clear that the methods overlap in many ways – e.g. *document analysis* and *automated techniques* have many similar traits. The reason for separating the methods and describing them separately is to elucidate which options a researcher has when planning a study and to introduce methods that will become relevant in the later sections of the chapter, as a source of inspiration for the development of a new data capture tool and related research methodology.

4.4.1 INTERVIEWS AND SURVEYS

Interviews and surveys are here grouped together, as surveys can be thought of as a type of structured interview [Robson 2011]. In *structured interviews*, the questions asked to the interviewee (or respondent in the case of surveys) are phrased beforehand and formulated word-by-word, to avoid discrepancies between responses. Structured formats are inherently scalable as the interview can be conducted by a person without prior knowledge of the research project. Surveys do not need an interviewer at all and for this reason, they constitute a very efficient way of gathering very large amounts of structured data. Even so, one should not underestimate the effort needed in engaging respondents.

1.1.1.1 EXAMPLE: THE PANEL STUDY FOR ENTREPRENEURIAL DYNAMICS

[Reynolds et al. 2004]

Interviews and surveys together form a basis for a large share of the extant entrepreneurship studies. In entrepreneurial process studies, the Panel Study for Entrepreneurial Dynamics with its more than 1200 responses from nascent entrepreneurs constitutes the most elaborate study of entrepreneurs over time. The basis for the study is summarised in the figure. Semi-structured telephone interviews were used as a basis for screening and re-engaging interviewees after 12 months. These interviews were then followed up by a 10-12 page survey sent by regular mail.

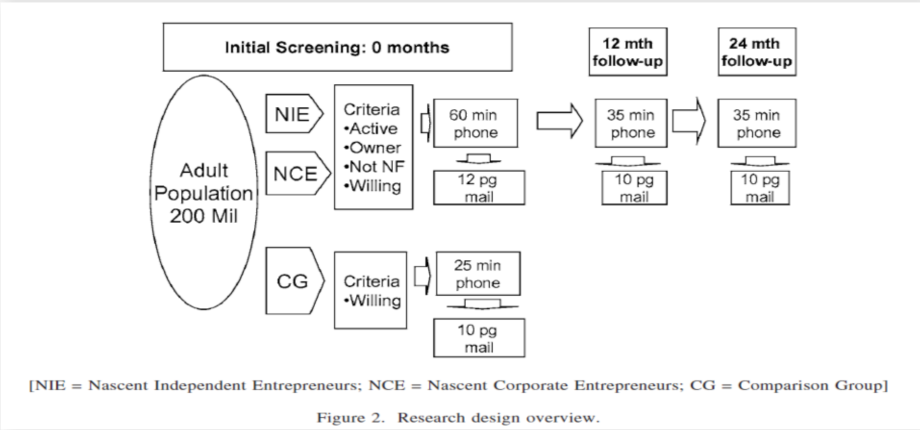


Figure 20: The process of gathering data through interviews and surveys [Reynolds et al. 2004]

Another very widely adopted interview format is the semi-structured interview, where the dialogue between interviewer and interviewee takes point of departure in a set of predefined questions and/or topics. From here, the interviewee is allowed to digress and, in doing so, reveal new dimensions of the phenomenon being studied. This *explorative* ability of the semi-structured interview does however come at a cost, as the digression of the interviewee can quickly fall outside the scope of the study. To moderate the interview, a person with an insight into the research project is needed, which often means that the researchers themselves need to do the interviews.

In Table 7, an overview is provided for the evaluation of each method, based on the defined requirements. An “x” indicates compliance with the stated requirement. A number of tools are only in partial compliance or require certain conditions – these instances are marked with “(x)”.

4.4.1.1 EVALUATION OF INTERVIEWS AND SURVEYS AS ENTREPRENEURSHIP PROCESS RESEARCH TOOLS

Interviews and surveys can easily be designed to capture data on the theoretical components of entrepreneurship. The same goes for the technological dimensions stated in the requirements.

Conversely, when dealing with the process related requirements relating to capturing dynamic data in high temporal resolution (activities of duration less than 10 seconds), the method encounters problems as surveys and interviews are usually prompted by the researcher (as opposed to certain dynamics in the process) and because they represent the interviewee/respondent’s *post-hoc* account of the process. The former makes it exceedingly difficult for the researcher to ensure that data is captured close enough to the events to justify a credible description. The *post-hoc* nature further decreases the *descriptive validity* of the process description. Also, the interview and the survey are obtrusive to the entrepreneurs who need to allocate time and resources to respond to the questions of the researcher.

Interviews and surveys are among the most established tools in qualitative research and for this reason, validity issues, questions of generalisability and bias are well understood and the qualitative researcher is well positioned to handle these. Similarly, interviews and surveys are well-established methods for *triangulating* interpretations in conjunction with other sources (e.g. participant observation).

4.4.2 PARTICIPANT OBSERVATION

Participant observation is the method of choice for ethnographic researchers looking to explore the behaviour, culture and characteristics of people or groups of people [Malterud 2001; Huberman & Miles 2002]. The variations on the method have been successfully used in a variety of fields including design- & innovation research [Bucciarelli 1988; Hales 1986]. The central notion of participant observation is that observing what the participant does is a more reliable source of data than the participant’s own verbal or written account of what he/she is doing.

The observer (the researcher) in a participant observation study can adopt several different tactics [Robson 2011]. As a *pure observer*, the observer follows the participants without them knowing they are being studied. This approach is particularly useful if *reactive effects* are a worry – i.e. the researcher is biasing the result. In adopting a role as pure observer, the researcher is unable to ask clarifying questions and further investigate observations.
The opposite of a *pure* observer is a *participant as observer* where the observer becomes a part of the group, participates in the activities and explicitly reveals his/her research objective. In this approach, the researcher has much better opportunities for engaging in a dialogue with other participants. According to Miles & Huberman, such an integrated

approach to ethnographic research has an inherent schism, in that the closer the observer gets to the participant, the better the data, but at the same time the observer's disruption of the phenomenon increases [Huberman & Miles 2002].

1.1.1.2 EXAMPLE: ANALYSING THE ENGINEERING DESIGN PROCESS IN INDUSTRY

[Hales 1986]

In design research, the studies of Crispin Hales represent the first attempts on ethnographic studies of engineering design processes. Over a period of 2.8 years, Hales worked on a participant as observer role, meaning he was an integrated part of the R&D department contributing to the development process like all other engineers.

During his participation in a large multi-disciplinary project, he continuously gathered notes and captured events. During this time he identified 1373 interchanges between employees or separately identifiable events. He made 1180 pages of diary notes, 76 hours of audio tape recordings, 116 weekly reports and 6 design reports. With this data, he was able to build a model for the processes and interactions in the project company – see the figure.

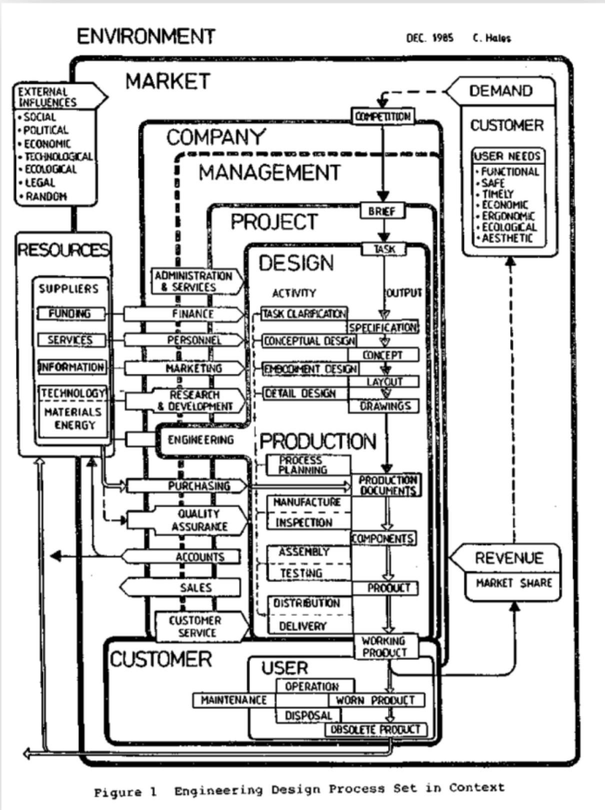


Figure 21: The engineering design process model emerging from Hales' participant observation study. [Hales 1986]

In certain cases, the researcher has an emancipatory agenda and wishes to directly affect the phenomenon. In such cases, the goal of the study is to instigate and create changes in the phenomenon rather than to avoid such effects. This *constructionist* angle on participant observation is called *action research* [Greenwood et al. 1993].

4.4.2.1 EVALUATION OF PARTICIPANT OBSERVATION AS ENTREPRENEURSHIP PROCESS RESEARCH TOOL

Just like interviews and surveys, participant observation can be used for capturing data and describing the components of entrepreneurship, entrepreneurial process and technology. Indeed, interviews and surveys are often a part of participant observation studies.

In participant observation, the researcher is on location with the entrepreneur. However, as was described when setting the requirements, the nascent entrepreneur works at unpredictable times and locations. The rest of the time is spent on other things, which might be relevant to the study. For this reason, the method of following the entrepreneur around can be very inefficient and disturbing to the entrepreneur. Being in the right place at the right time is a major logistical challenge.
One solution to this challenge could be so-called *auto-ethnographic* studies where the participants are themselves tasked with documenting their behaviour [Duncan 2004]. It goes without saying that the researcher and participant become exceedingly difficult to separate in such approaches.

In any case, the motivation for why an entrepreneur should allow an observer to follow and disturb him or personally engage in an auto-ethnographic study is unclear, as the value created by such efforts and investments come on the longer term. This makes the research effort irrelevant to the entrepreneur.

With regard to the requirements pertaining to research rigour, validity issues in participant observation studies are well understood [Hayano 1982; Goetz & LeCompte 1981] and relate closely to the type of observer used (e.g. *pure observer* vs *participant as observer*).

4.4.3 STRUCTURED OBSERVATION

An observation study can be characterised by a more or less integrated observer, but it can also be characterised by varying degree of structured observation. *Structured observation* studies are at one end of this continuum for structure. Here, observations are documented according to a strict structure – often called a coding scheme [Gero & McNeill 1998; Robson 2011]. This coding scheme is usually derived from preceding explorative studies or from theory. As such, the resulting *description* is strongly coupled to the underlying theory creating a solid basis for *descriptive validity.*

The structured descriptions have the advantage of being easy to analyse, using quantitative tools and to compare to other studies. In the most rigorous structured observation studies, the researcher observes and codes the observations without interfering with the participants (similar to a *pure observer*). The structured observation departs from the *emic* idea of understanding a phenomenon in terms of the participants' point of view (see section on *interpretive validity*). Rather, the coding scheme requires the researcher to interpret (an *etic* perspective) and assign components of the coding scheme to the observed phenomenon. For this reason, the evaluation of *inter-coder reliability,* where the same observations are coded by two or more different researchers is crucially important. The appropriateness of mapping a given observation to a theoretical construct relates to the *construct validity* of the study.

1.1.1.3 EXAMPLE: ANALYSIS OF DESIGN EPISODES
[Gero & McNeill 1998]

To better understand the work of designers, Gero conducted a number of studies where designers working on a task were observed using video equipment. As the respondents in Sarasvathy's think-aloud studies, the designers were asked to verbalise their actions. Each session had a total duration of one hour.

The video and sound material was then coded based on a predefined structure. The figure shows the resulting activity within each category of the coding scheme over time. The codes in the coding scheme are seen on the left axis.

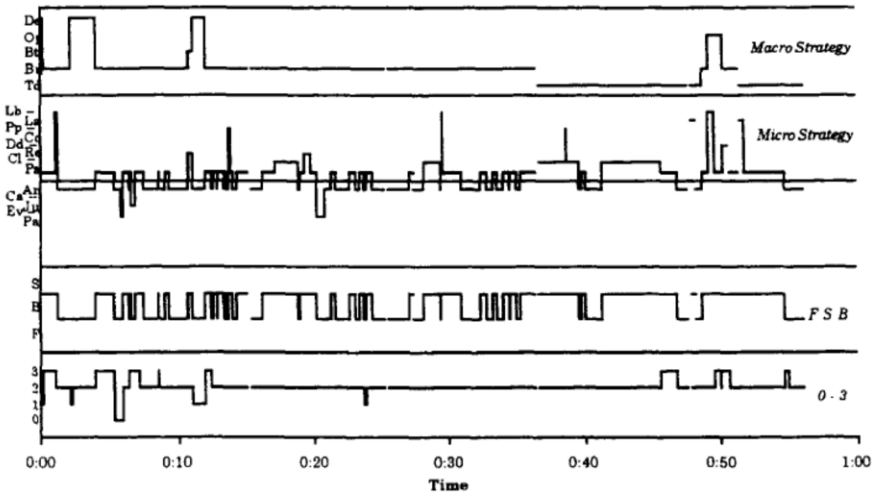


Figure 2 Activity chart for the first design episode

Figure 22: Timeline for design activities described using coding scheme [Gero & McNeill 1998]

Instead of having different researchers code the same material, Gero has the same researcher code the material, but at different times (10 days apart). The idea is that any fixations that the coder would get from the first coding session would be forgotten at the time of the second session.

4.4.3.1 EVALUATION OF STRUCTURED OBSERVATION AS ENTREPRENEURSHIP PROCESS RESEARCH TOOL

As is clear from the introduction of the structured observation method, the method fares very well in terms of the research rigour categories listed earlier in the chapter, as validity issues can be explicitly mitigated in the underlying coding scheme.

Seeing that structured observation is dependent on a pre-defined structure it is more likely to yield consistent data outputs for similar events at different times. This makes the method particularly useful in tracking changes over time – a central requirement for research methods for entrepreneurship process research.

The coding scheme also provides a good basis for explicitly identifying the conceptual components of entrepreneurship and technology. However, as stated in the forming of the requirements, the current understanding of these components is weakly rooted in empirical evidence [Moroz & Hindle 2012; Neergaard & Ulhøi 2007], meaning that the concepts are likely to change or become obsolete with increasing empirical evidence. In other words, the *explorative* capability of the research method is important. The structured observation method is weak in this regard, as it requires a static structure throughout the study.

Another weakness of the structured observation method is that the *interpretive* step (coding) is resource intensive typically requiring several hours of coding per hour of recorded data. Entrepreneurship processes can be partly understood by looking at shorter durations of activities, but to really understand the gestation process of a new venture, it is clear that a longer-term perspective is needed. For instance, the *Panel Study for Entrepreneurial Dynamics* [Reynolds et al. 2004] dealt with processes unfolding over a 24 month period. To capture data from the process over such extended periods of time, the way in which structure is applied needs to be optimised in a way that enables sufficient temporal detail, but which also captures to long-term changes in the central concepts. As long as the researcher is the basis for *interpreting* large amounts of data, it will be difficult to strike an acceptable balance in this trade-off.

Last, but not least, the structured observation method is challenged by the fact that studies require extensive preparations to ensure as little disturbance of the process as possible, while at the same time getting the necessary data. In the haphazard world of entrepreneurship processes, the ability to plan ahead is a rarely present. This could be mitigated by coordination between the entrepreneur and the researcher, but this would require that scarce resources be spent on something that does not contribute any direct value to the venture.

4.4.4 DOCUMENT ANALYSIS (HERMENEUTICS)

By following the participant, the researcher can gain valuable insights about the studied phenomena. Interesting tendencies can be observed in more detail or if the observer is also a participant, questions can be phrased to elucidate points of interest. However, as discussed, the direct engagement with the participant creates a number of problems; both with regard to planning and resource expenditure, but also with regard to biasing issues – i.e. the researcher disturbing the phenomenon in various ways.

An alternative method for collecting data from a process is to use unobtrusive measures [Robson 2011]. Here, the traces of the process are followed – the document trail, the user of toner, the IP addresses employees are communicating with and so forth. If the measure used is in the form of physical evidence produced by the process, it is known as an *accretion measure*. If the physical evidence is in the form of a reduced quantity (e.g. printer toner) it is known as an *erosion measure*.

1.1.1.4 EXAMPLE: PARALLEL R&D PROJECTS AT DANFOSS POLYPOWER
[Ravn & Guðlaugsson 2015]

The Danish technology company Danfoss Polypower is specialised in a novel type of rubber actuator – often referred to as artificial muscles. These Electro Active Polymer (EAP) materials hold great promise for use in various consumer- and industrial applications. To accelerate the technological uptake, a research project was initiated in collaboration with the Technical University of Denmark, which was aimed at mapping the issues faced by development teams and at understanding the different venues for further developing and integrating the technology.

Nine work packages working in parallel were followed – four of which dealt with the integration of the technology in new products or so-called technology prototypes. To understand the challenges facing the R&D teams, the researchers chose to rely on document analysis in the form of monthly progress reports, which were used to keep management up to speed on the progress of each work package.

In using these reports documenting the challenges and dispositions of the R&D team, the research team was able to build a good understanding of the technological difficulties without having to continuously follow the process and thus avoiding reactive effects. In the figure, the data extracted from the monthly reports is shown in a coded format.

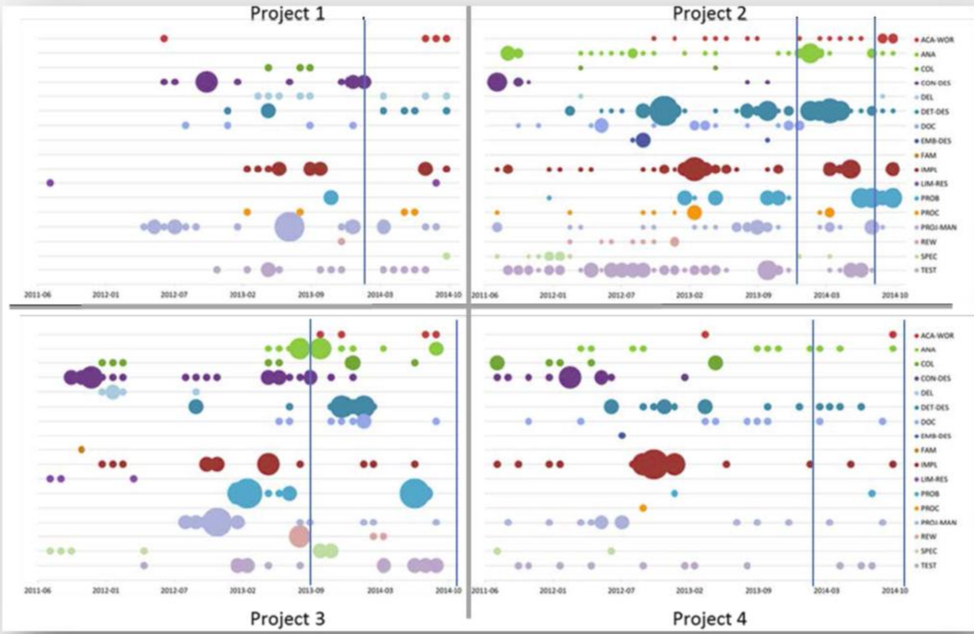


Figure 23: Illustration of prevalence of various task codes over time for the four projects. [Ravn & Guðlaugsson 2015]

For the sake of disclosure, it should be mentioned, that the research team also utilised other research methods in trying to understand the technological development – including participant observation with the researchers in a participant as observer role.

A common *accretion measure* for human activity is the documents produced as the processes unfold. These documents could be weekly reports, emails, chat messages, specifications etc. The use of documents in understanding human activity is known as *hermeneutics.* Understanding human processes in terms of the documents produced by the participants comes with its own set of validity issues. On the plus side, the account is inherently *emic,* i.e. it provides a description based on the participant's perspective.

Seeing that the participant defines the perspective and formulates the document, the (unobtrusive) researcher has no say in what type of data is being created. Even if the documents are standardised (e.g. weekly reports), there is now way for ensuring that consistency and level of detail is sufficient for answering the questions of the researcher. In other words, the researcher has to make do with the available data in trying to support the theoretical discussion. This poses a potential threat to the *construct validity* of the study.

4.4.4.1 EVALUATION OF DOCUMENT ANALYSIS AS ENTREPRENEURSHIP PROCESS RESEARCH TOOL

Entrepreneurial processes are unpredictable and very heterogeneous. It is likely that the emergence of a venture will result in a mass of documents being produced, but it is less likely that these documents will maintain formats and themes over time. The *document analysis* method may very well be able to support research efforts relating to the theoretical requirements listed in Table 6 (page 66) for entrepreneurship and technology, but there is no way for the researcher to know this beforehand. This makes an *explorative* approach to document analysis the most appropriate for entrepreneurship process studies.
The causal links and dynamics uncovered using document analysis will be limited to the events and activities described in the documents. Beyond this, the researcher will have to find other methods for describing the phenomenon, thereby losing the advantage of the unobtrusive measure.

From a research methodology standpoint, the document analysis is unlikely to yield tidy data in standardised formats. As already indicated the theoretically founded *interpretive*- and *descriptive validity* of accounts is challenged by the fact that it is difficult to gauge the appropriateness of a given theory before initiating a study. Generally, many of the validity issues are prevalent, as the researcher has to use whatever is made available by the team. If a team adopts a procedure of reporting weekly or monthly on activities, the researcher will have a good basis for arguing *internal generalisability*, but such structure is not commonplace in startups. Rather, *internal*- and *external generalisability* will be challenged by the researchers' inability to support theoretical concepts with empirical evidence (*construct validity*). The same can be said for *triangulation*; emails, reports, chat messages and other things can be used in conjunction to strengthen the account, but only if such documents exist and only if they describe the same parts of the phenomenon.

4.4.5 AUTOMATED TECHNIQUES (COMPUTER BASED)

The proliferation of software tools has resulted in an exponential growth in the availability of electronic data coming from processes of various types. CAD software creates versions of designs, which can help the researcher follow the evolution of the design, accounting systems, and internet bank services enables insights into the financial performance of companies and so forth. The resulting data can often be seen as an *unobtrusive measure* because the participants are producing it regardless of the research objectives of external parties (the researchers). However, there are also many examples of studies using automated techniques introduced by researchers with the two-sided objective of creating value for the participants and capture data for the researchers. In this case, *reactive effects* are bound to occur.

1.1.1.5 EXAMPLE: THE FUTURE LEARNING ENVIRONMENT

[Lahti et al. 2004]

This study concerns the behaviour of designers in software supported collaborative environments. To support the study, a collaborative tool for sharing notes and sketches was created called the Future Learning Environment or FLE (see http://fle3.uiah.fi/). Groups of design students were then given a specific task – development of clothing for premature babies – and told to use the software tool as a basis for solving the task.

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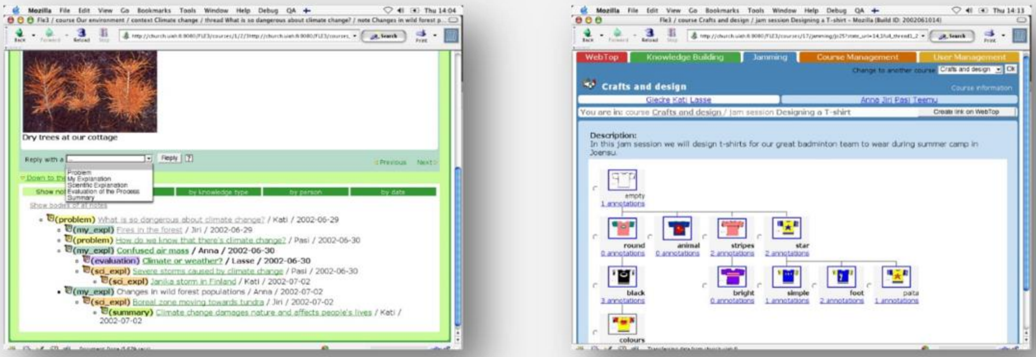

Figure 24: Screenshots from the Future Learning Environment interface [Lahti et al. 2004]

By using the tool, the students were supported in their work and at the same time, the researchers got direct access to the materials created: Drawings, comments, communications etc. These pieces of data were then analysed using qualitative methods, such as protocol analysis [Gero & McNeill 1998] *with two independent coders. An example of the output from this coding effort is shown in the graph below, which shows the distribution of various types (codes) of activities over time.*

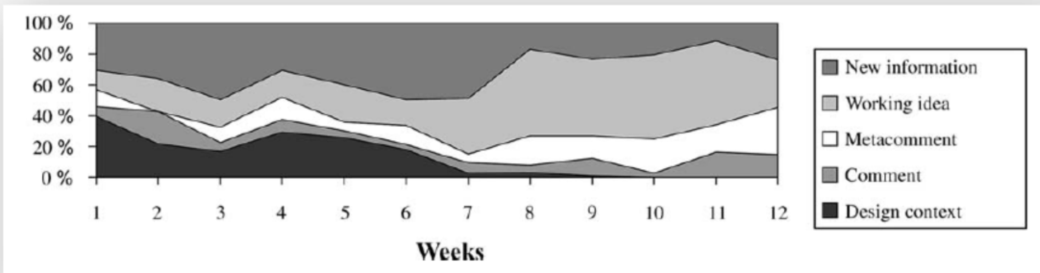

Figure 25: The prevalence of various activity codes over a 12-week period [Lahti et al., 2004]

One major benefit of the automated techniques is their inherent scalability. When designed and implemented, the software can be used in many cases with limited need for the researcher being present. Also, similar to structured surveys and interviews, the software ensures that data is gathered in a consistent way.

4.4.5.1 EVALUATION OF AUTOMATED TECHNIQUES AS ENTREPRENEURSHIP PROCESS RESEARCH TOOL

By having a software define the types of information, which are collected, the researcher can ensure that the knowledge relevant for supporting the theoretical discussion is indeed gathered. This in conjunction with comment fields and other more open-ended input features can help ensure the capture of data relevant to the current theoretical understanding and data that might reveal new theoretical venues. As such, the automated techniques can be designed to fulfil the requirements coming from the entrepreneurship phenomenon and the requirements relating to technology. The scalable and structured nature of software also makes it easy to capture data continuously and thereby describe the dynamics of the process. As automated techniques are in part *fixed research designs,* the researcher needs to know the theoretical underpinnings of the study beforehand as well as their coupling to what is actually measured, described and interpreted. Unlike other structured approaches, the theoretical basis is locked-in during the design of the software – the *descriptive validity* is embedded in the software. If a change occurs that prompts the researcher to change the way in which data is gathered, this can be exceedingly difficult, as these changes have to be implemented in the source code.

By using different types of data – e.g. sketches, natural language input, sound etc., the researcher can also use the software platform to triangulate descriptions and interpretations.

4.5 CONCLUSION: LACK OF RESEARCH METHODS FOR RESEARCHING ENTREPRENEURSHIP PROCESS

The evaluation of existing research methods in terms of the list of requirements revealed that a number of existing methods could potentially yield valuable insights into the entrepreneurship process phenomenon. All the methods presented comply with many of the requirements, but none of them manages to cover all the bases. In particular, one requirement is left unresolved by all methods: *"R7.3 – Create value for the entrepreneur".* Due to the nature of entrepreneurship processes, the entrepreneur has little reason for allocating time and resources toward participating in a research project. One possible exception to this could be *participant observation* studies where the researcher contributes actively to the project (*participant as researcher*). As indicated, this type of *constructivist* epistemology comes with its own set of challenges in the form of *bias issues* and *reactive effects.*

Most of the methods are also challenged by the unpredictable nature of the entrepreneurship process and the heterogeneity in terms of contents and themes. This makes it very difficult to plan studies and to follow the entrepreneur.

4.6 REFLECTION ON CHAPTER CONCLUSIONS

Despite various shortcomings, the existing tools provide an ample basis for improving the rather poor empirical foundations for entrepreneurship process research. At this point, one could instead choose to pursue a study of technology entrepreneurship processes using existing tools – such as e.g. the auto-ethnographic method used in chapter 3.

However, seeing that the field is so poorly researched and no standard practices exist, the timing is right for contemplating how one could create a research method specifically aimed at entrepreneurship processes.

Furthermore, in light of the heterogeneity of the phenomenon, it would be useful to develop a method able to draw data from many projects at once, as this would help in understanding how different contexts affect the entrepreneurship process. Having only a handful of projects documented would make any *external generalisations* very difficult and conclusions would have to be limited to the particular sample.

CHAPTER 5:
A NEW TOOL FOR ENTREPRENURSHIP PROCESS RESEARCH

RQ2.3:
How can entrepreneurship research be strengthened to better cater to the needs of technology venture processes?

In this chapter, the requirements formulated in chapter 4 and the experience gathered in evaluating existing research methods will be used as a basis for developing a new method, which is tailor-made for entrepreneurship process research.

5.1 CHAPTER RESEARCH DESIGN

In building the research tool, methods and bodies of knowledge from various areas have been utilised. These sources are summarised below.

5.1.1 CONCEPTUALISATION OF A NEW RESEARCH TOOL

In this first section, a new tool for capturing data from entrepreneurship processes is conceptualised. *Grounded theory* [Glaser & Strauss 1967; Bryant & Charmaz 2007] is used in conjunction with *natural language clustering* software [Eck & Waltman 2011], to create an exhaustive tagging system for the tool developed.

A number of theoretical references from various research fields are brought in to create the concept for the research method. This includes models from design and innovation research [Schön 1984; Fowler & Highsmith 2001; Koen et al. 2002], from entrepreneurship research [S. A. Shane 2000; Read et al. 2010], from cognitive psychology and from anecdotal literature [Ries 2011].

5.1.2 TESTING THE RESEARCH TOOL

Once conceptualised, the tool is then tested in a similar way as with a normal software product, meaning that early versions are given to test users and feedback captured by way of surveys and interviews. The section also uses the works of [Miles & Huberman 1984; Huberman & Miles 2002] and their approach for drawing conclusions from qualitative data, which is divided into three stages:

1. *Data condensation*
2. *Data display*
3. *Conclusion drawing / verification*

Using this approach, new ways for displaying and understanding the tool's data are developed, alongside the actual tool.

5.1.3 INTERPRETING LARGE AMOUNTS OF DATA

In the final section of the chapter, a method for testing existing theories and deriving new theories from the data gathered is proposed. This section builds on ideas from *grounded theory* [Glaser & Strauss 1967; Charmaz 2006], but it also relies extensively on tools from *machine learning* and *artificial intelligence literature* [Sarawagi 2007] and *natural language processing* tools [Hofmann 2001].

5.2 CONCEPTUALISATION OF A RESEARCH METHOD

The point of departure for the conceptualisation of a new research tool is the list of requirements formulated in the previous chapter. This list ensures that the new tool is strongly aligned with the phenomenon in focus (*entrepreneurship processes based on advanced technology*), as well as the body of knowledge that exists concerning rigour within qualitative research.

In addition, as pointed out, the methods evaluated in the last chapter have many qualities, which could be beneficial to a new research tool. For this reason, the positive aspects of the existing tools are used as a source of inspiration in the conceptualisation of a new research tool. Below, the favourable features of each method presented are quickly summarised. The limitations of each method are covered in detail in the previous chapter and will not be reiterated here.

- *Interviews / surveys:* The ability to inquire in a structured manner and uncover details about a given situation, while at the same time allowing for the interviewee to digress and divulge information relevant to the understanding of the phenomenon (*semi-structured* interview). Electronic surveys constitute a very efficient method for gathering large amounts of structured data with a minimal resource consumption.

- *Participant observation:* By following the entrepreneur, this method enables the researcher to get a deep causal understanding of the cognitive strategies of the entrepreneur and his/her interactions with various elements in the environment.

- *Structured observation:* By structuring the observed behaviour of and the information created by the participants, the researcher can create a consistent and theoretically sound account of the observed phenomenon.

- *Document analysis:* This unobtrusive method enables the researcher to capture data from the process without disturbing the process. Also, it ensures an *emic* interpretation of the events unfolding.

- *Automated techniques:* By supporting the process, the researcher can motivate the participant to provide data through e.g. a software system, thus eliminating the need for the researcher to actively observe the phenomenon.

With these favourable characteristics in mind, the following sections will discuss in detail how the theoretically derived and research methodology related requirements will be addressed in the design of the new research tool, which will henceforth be referred to as the Entrepreneurship Process Research (EPR) Tool.

5.2.1 A CONCEPTUAL FRAMEWORK

As discussed in chapter 3, there is a need for establishing an understanding of the entrepreneurship process phenomenon through empirical evidence [Neergaard & Ulhøi 2007; Moroz & Hindle 2012]. The *interpretive- and theoretical validity* of a study is highly dependent on the researcher picking an appropriate underlying conceptual framework – i.e. an understanding of the parts of the phenomenon and their relations. Miles & Huberman provide the following definition [Miles 1994]:

> "*A conceptual framework explains, either graphically or in narrative form, the main things to be studied – the key factors, constructs and variables – and the presumed relationships among them. Frameworks can be rudimentary or elaborate, theory driven or commonsensical, descriptive or causal.*"

In this regard, a variety of conceptual elements and relationships has been proposed as basis for a theoretical understanding of the entrepreneurship process phenomenon. Although convergent on some points, these links and components generally vary quite significantly between scholarly contributions. This makes it difficult and unfeasible to try to impose any of these theoretical models onto the design of the research method – i.e. a *fixed research design* [Robson 2011]. Rather, at this point, the method is most useful if it enables an *explorative* study of the phenomenon. Still, the use of a conceptual framework would bear with it a number of advantages (consistency, efficiency, generalisability). For this reason, it is interesting to consider ways in which a *fixed design* could be used as a basis for an *explorative study* (flexible research design).

Rather than trying to create a holistic framework encompassing the diverging concepts currently used, it was decided that a format should be conceived, which is able to contain the current concepts while at the same time allowing new concepts to emerge. In this regard, the author has drawn inspiration from resource based descriptions of entrepreneurship [Baker & Nelson 2005; Widding 2007; Widding 2005]. Put simply, the nascent entrepreneur has a *pool of assets,* which he/she uses in building their venture – this could be anything from capital resources, knowledge and competencies to network relations, government policies and intellectual property rights. Everything, which could be conceived as valuable to the venture is considered an *asset.* This idea of an *asset perspective* encompasses many of the conceptual components mentioned in chapter 3.

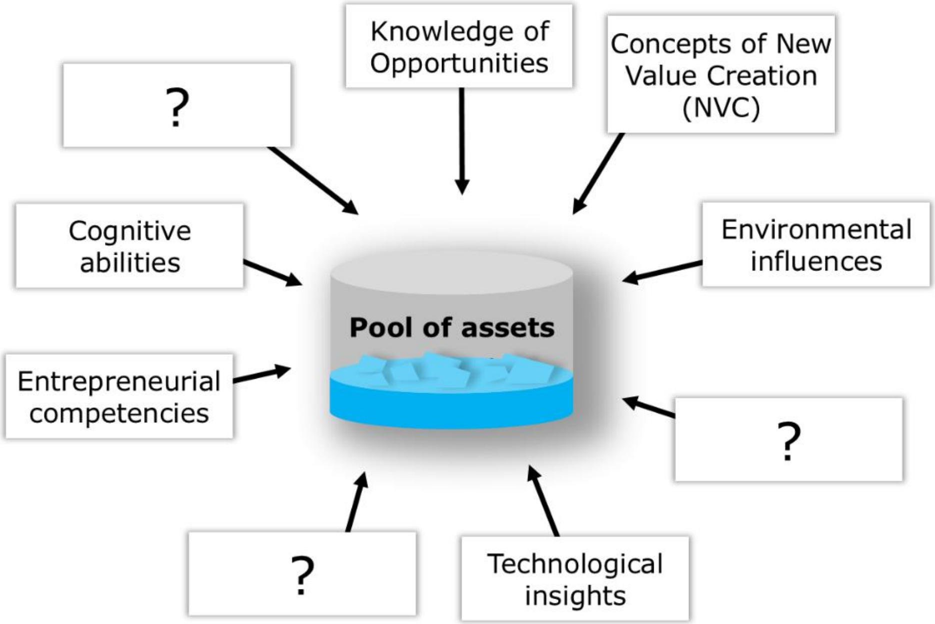

Figure 26: The entrepreneurial pool of assets (note the question marks indicate the ability to encompass emerging concepts) [own]

This very simple form deals with the *things* in the conceptual framework. It does however not deal with how entrepreneurial action (a premise for the process) plays a role in leveraging existing assets and building new ones, or in other words; how entrepreneurial action plays a role in transforming inputs into outputs (see Figure 18). As established in chapter 3, a *process dynamics* perspective should be favoured over the alternative process descriptions (e.g. *stage models* and *static frameworks*).

This process dynamics perspective should account for how the venture responds to emerging situations and how cognitive strategies (e.g. *effectuation* or *bricolage*) are applied in the longer and shorter term. In Figure 27 a conceptual framework is presented, which combines the *asset* perspective with dynamic processes undergone by the entrepreneur. The components of the framework will be described below.

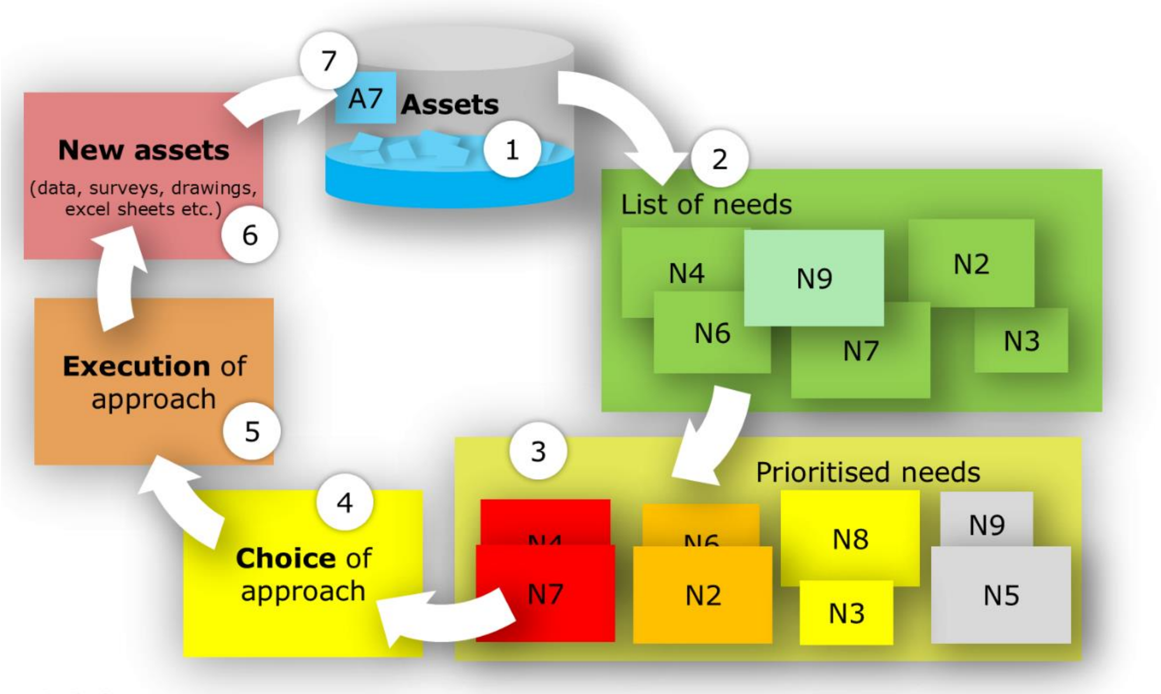

Figure 27: A conceptual framework for entrepreneurship processes [own]

For a given pool of assets (1), the entrepreneur (or team) formulates a number of *needs* for acquiring new assets (2). In extension of the *asset* definition introduced above, the needs can relate to literally anything the entrepreneur can think of; e.g. *"we need a better understanding of the customer"*, *"the group has to gain some knowledge about dredging"*, *"I need a contact in the Danish business angel environment"*, *"we need to design a visual identity for the venture"* and *"we need to acquire rights for the exclusive use of the technology"*.

The participant then goes on to prioritise the needs that have been formulated (3) – e.g. at a given point in the process there might be a need for a visual identity, but this need has a lower priority than other needs. One could argue that often needs will only be formulated when they are critical, but to avoid any unfounded assumptions, the need formulation and prioritisation steps have been separated.

The steps so far (1-3) have been concerned with the entrepreneur's ability to understand the given situation (context and assets). These steps help in defining the input for the subsequent action of the entrepreneur. In step (4), an approach is chosen for addressing the need. This approach could be based one of the *effectual* principles or merely an ad-hoc notion of what might address the need. After this, the entrepreneur starts executing the approach (5). The execution will often be supported by working documents and communication with various stakeholders in and outside the team.

Eventually, the entrepreneur will finish executing the approach (or give up) and reach a final result (6). This result can take many forms, such as prototypes, video recordings, spreadsheets, written documents etc. Regardless of what form it takes and whether it is a success or not, the result now becomes a part of the pool of assets (7).

The relation between this conceptual framework and the input/transformation/output model defined in chapter 3 can be seen in Figure 28.

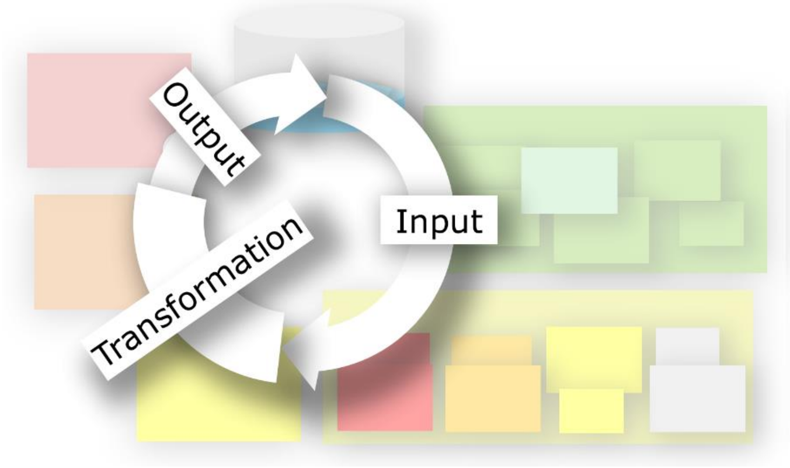

Figure 28: The relation between the conceptual framework and the input/transformation/output model discussed in chapter 3. [own]

The advantage of the conceptual framework described above is the ability to explicitly relate the actions of the entrepreneur to the given inputs (pool of assets and context) and thereby provide a basis for understanding the cognitive strategies (which are also explicitly stated) employed. Also, the framework provides a basis for understanding how the actions of the entrepreneur play a role on strengthening the asset base of the emerging venture.

5.2.1.1 CRITIQUE OF CONCEPTUAL FRAMEWORK

The framework presented above has a number of issues, which might limit its applicability to the entrepreneurial phenomenon (the *theoretical validity).* One issue is the fact that the actions of the entrepreneur can be understood in terms of a reflexive evaluation of the current situation (the *inputs* or the *needs* in the framework). Is it not possible, that in certain cases, the entrepreneur acts without having a clear idea of why he or she is pursuing a particular path?

Also, the conceptual framework is unclear in terms of the timescales covered; does it deal with the *micro strategies* or the *macro strategies* of the entrepreneur or both?
For now, these questions will remain unanswered. They will however be taken up for further review in section 5.3.3.4 (page 107), where the embodiment of the method and conceptual framework are discussed.

5.2.2 VALUE CREATION FOR ENTREPRENEUR

In chapter 3, the evaluation of existing research methods revealed one requirement, with which all methods failed to comply. This was requirement 3.3: "*Create value for entrepreneur*". This failure to comply was due to the significant differences that exist between instances of entrepreneurship. These differences render any conclusions made for one project at one time irrelevant to other times and projects. Furthermore, the resource scarcity facing most entrepreneurial efforts makes it unlikely that entrepreneurs will choose to allocate resources to participating in an academic study.

To motivate the entrepreneur to participate in a study, the research method has to be either completely unobtrusive or justify itself by creating value for the entrepreneur in the shorter term. From a research rigour standpoint, these are two very different scenarios. The unobtrusive scenario is aligned to a *realist* perspective, whereas the value creation scenario is more likely to fall within a *relativist* or *critical realist* paradigm of research, where the researcher is a part of the phenomenon being studied.

The author was unsuccessful in conceptualising any ideas for unobtrusive methods, which also complied with the remaining requirements set forth. Therefore, the choice was made to proceed with conceptualising a method based on value creation for the entrepreneur and to observe methodological caution in doing so.

Two sources were used as a basis for conceptualising a mechanism for creating value for the entrepreneur: The auto-ethnographic study described in chapter 2 and the conceptual framework developed in the previous section.

5.2.2.1 THE AUTO-ETHNOGRAPHIC STUDY: THE VALUE OF DIARY NOTES

In the auto-ethnographic study of the commercialisation process for a novel flue gas cleaning technology, the entrepreneurs chose to keep a simple diary to describe the process and enable later interpretation. The diary was based on three simple questions:

1. *What was important today?*
2. *How did we approach the challenges?*
3. *What did we learn from it?*

Despite being made for research purposes, the diary turned out to be valuable in another way: The entrepreneurs realised that the information held in the diary notes provided an excellent basis for making informed decisions about the next steps in the process.

As such, the research method became a basis for supporting the everyday activities of the venture. Arguably, the use of the diary notes had *reactive effects* in that the imposition of a structure of reasoning (the questions) could conceivably lead to the team following a different path than would have otherwise have been the case. However, one could also argue that the questions posed are in no way novel and that the cognitive strategies of the entrepreneurs would in any case be based on similar lines of inquiry. On one hand, the questions do not dictate any themes or courses of action and for that reason, they cannot be said to inspire new behaviour. On the other hand, the diary sheets and the standardised format did provide a platform for gaining an overview and more efficiently managing the process. It should be noted that this performance improvement is the subjective view of the entrepreneurs and no objective proof exists. In any case, this experience shows that the research EPR tool can be formulated in a way that (at least subjectively) creates value for the entrepreneur.

5.2.2.2 STIMULATING A PROCESS AT THE INFORMATION SHARING LEVEL

In parallel with the auto-ethnographic study, a number of software tools for supporting the entrepreneurial process were investigated in the hope of finding potential candidates for *automated data capture techniques.*

Online project management tools are widely used by projects of all sorts including entrepreneurial ones. Popular tools include *Lean Launch Lab* (www.leanlaunchlab.com/), *Podio* (www.podio.com), *Pivotal Tracker* (www.pivotaltracker.com/) and *Asana* (www.asana.com). All of these tools offer some type of project management assistance.

Some of the tools do this by applying a development model - e.g. agile development processes [Dybå & Dingsøyr 2008] in *Pivotal Tracker* – or by applying an information model such as the widely adopted Business Model Canvas [Osterwalder et al. 2005] (used in *Lean Launch Lab*). In other words, these tools are prescriptive in nature meaning that they provide project data of certain types.

Other tools such as *Asana* and *Podio* are general platforms that among other things provide communication and resource allocation features. Unlike the prescriptive tools, they will gather many types of data depending on the way they are used by the project team. The resulting project data will not be in a standard format.

The experience with various online project support tools led to the idea that perhaps a tool could be created, which allowed for many types of data to be collected (allowing for an *explorative* perspective), while at the same time ensuring that a structure was in place for providing the necessary context for each element.

The conceptual framework developed earlier was seen as a good candidate for such a structure, as it provides a structure for the process without prescribing particular problems or solutions. As was argued, the framework is a good (albeit simple) account of the entrepreneurial process. By helping the entrepreneur get the correct information and proceed to the next step in the framework the overall cycle time is reduced and the risk of making uninformed decisions is reduced. Figure 29 shows how supporting each step with relevant information could in principle help improve the overall cycle performance.

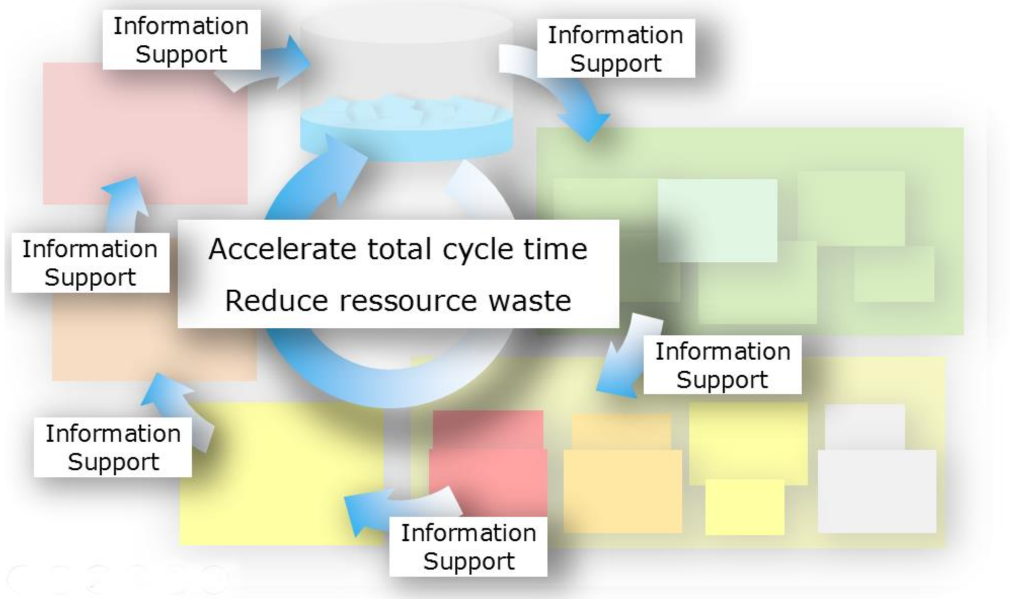

Figure 29: Information support for conceptual framework in order to increase cycle performance [own]

5.3 USING THE CONCEPTUAL FRAMEWORK

To test the use of the conceptual framework in a software tool for entrepreneurship processes (the EPR tool), three prototypes were developed. In this section, the design of the prototype and the learnings from testing it are discussed.

5.3.1 FIRST PROTOTYPE: BASED ON ONLINE SPREADSHEET

This prototype featured all the conceptual components and it was built using Google's Spreadsheet tool (www.google.com/sheets/about/). Below, screenshots of the very first version of the EPR tool are shown (see Figure 30-Figure 31).

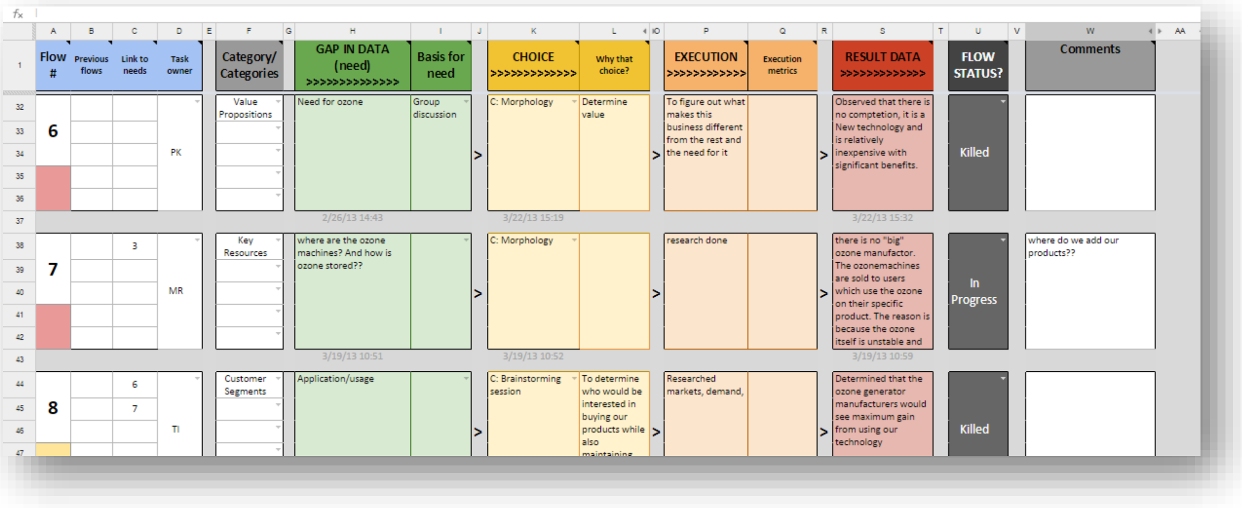

Figure 30: The main window featuring need description, choice of approach, notes on execution and result data. [own]

Figure 30 shows the main window, which is where the needs are added to the *list of needs* element in the conceptual framework (green boxes). The EPR tool also featured a "*basis for need*" column (also green), where the team could specify if the need came about because of a *group discussion*, *mentor input* and so forth.

A choice was made to use the Business Model Canvas as a basis for categorising the needs (see Figure 31). This was because the canvas had become a widely adopted format for representing a business. To link the need to the canvas, the user is required to specify to which category of the canvas the need belongs. In the far left columns, the number of the cycle (then called a *flow*) is listed along with a column for linking the present flow to previous flows. Also, if one need is solved using several approaches, the green need field can be left blank and the number of the related need can be specified in the column named "*link to needs".*

When a need has been formulated and categorised the user would proceed to the *need management* window, which is shown Figure 32. Here, the priority of this and other needs can be can be set and resources (team members) can be allocated. This window directly represents the *prioritised needs* element of the conceptual framework. Depending on the priority, the need will get a different colour. This colour is seen in the main window right under the flow number (Figure 30). The idea of separating the need prioritisation feature from the main window was to avoid clutter and to enable the team to gain an overview of the process on the overall (need) level. Furthermore, the goal was to explicitly separate the cognitive process of prioritising from the process of proposing solutions.

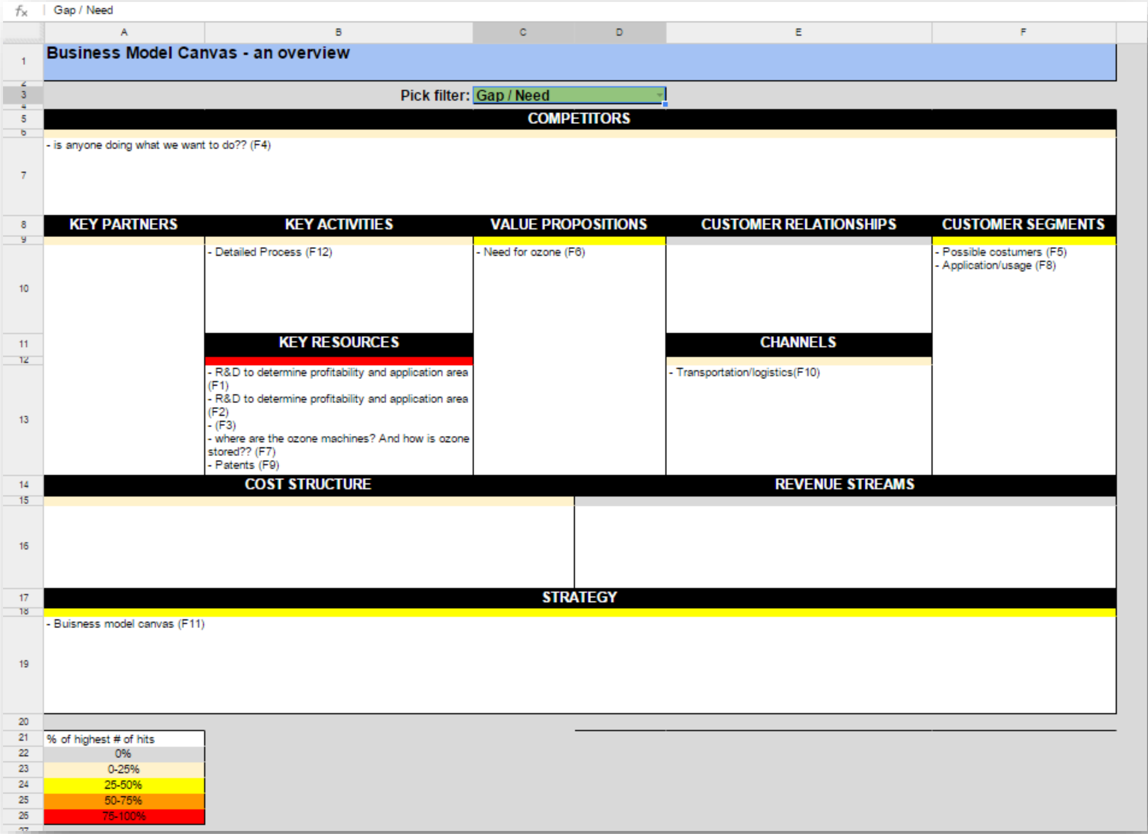

Figure 31: The "business model canvas" window, where the team can see the current needs, activities and results of the project in the standard Business Model Canvas format. The colour scheme was used to indicate parts of the canvas with any associated needs. [own]

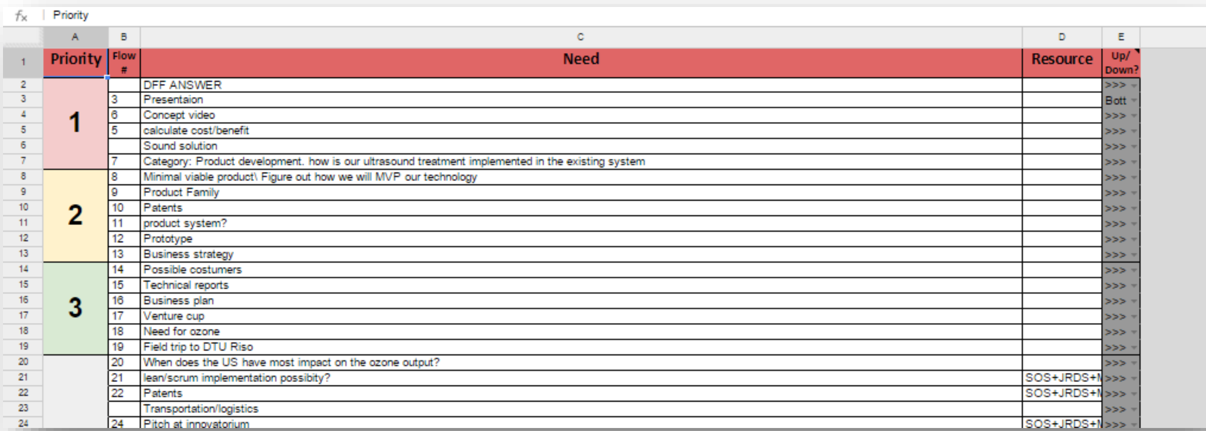

Figure 32: The "need management" window, where the needs' priorities are changed continuously [own]

At this stage in the method's development, the correct balance between structure and flexibility in the research design was still being explored. Consequently, this initial prototype had a pre-defined set of generic approaches (e.g. *brainstorming*), which the users could pick (yellow fields in Figure 30). If no appropriate choices were available, the EPR tool also featured a request field, where they could contact the researcher and ask for a new approach to be added. If accepted, this approach would be added to the list of options for all users of the EPR tool. The idea behind this was that the researcher could maintain control of the data in the EPR tool and allow for the number of options to grow in a structured manner. Finally, in line with the conceptual model, the EPR tool offered a field (orange) for reflecting on the execution of the approach.

5.3.1.1 TESTING THE FIRST PROTOTYPE

To test the first prototype, it was used as a support tool in a university project course dealing with advanced technology entrepreneurship. In this course, 11 startup teams of 4-5 master students from engineering and business degrees were given an advanced technology and instructed to build a new venture based on its technological advantages. The course ran for 13 weeks and each student spent an estimated (course norm) 16 hours per week on the project. Throughout this period, the teams were instructed to use the prototype version of the EPR tool as a basis for supporting the process. At the end of the term, the students were asked to evaluate the tool in an electronic survey (23 responses).

5.3.1.2 LEARNINGS FROM THE FIRST PROTOTYPE

The feedback given from the team during the process and as a response to the final survey revealed a number of issues with the EPR tool. The usability of the prototype was very limited and the teams generally expressed frustration with having to use the tool. Also, being based on a spreadsheet, the tool was prone to errors due to incorrect usage.
Examples of negative feedback:

> *"Somehow it felt complicated and a bit time wasting to use it and it had a lot of bugs..."*
> *"Too many bugs meant that there were long periods of time where the log was not usable. Too time consuming and overly complicated meant that it became a task in itself to fill out the log. The need manager was too slow to use, and therefore it was not helpful."*
> *"It doesn't work that well in practice, and i usually wanted to work on the project itself, rather than spending time updating the Development Log [name of project tool]"*

The balance between structure and flexibility was also mentioned by some teams as an issue:

> *"The template makes it hard to use if you have something that does not fit into a category"*

Despite this, some teams did express an understanding for the potential value of the EPR tool:

> *"I see the value in being able to look back on the development process, if you are able to keep good records."*
> *"The idea of organising our work process, to gain an overview is great, when you actually remember to use it."*

In general, the usability of the EPR tool was known to be poor even before the projects started using it. Therefore, the negative feedback on this was very much expected. The important learning was that despite the shortcomings, several of the entrepreneurial teams expressed an understanding of the potential value of such a tool.

At the time of its conception, the *business model canvas* was seen as an appropriate framework for categorising the contents of the process. The theoretical components of entrepreneurship theory were thought to fit well with the canvas format. Similarly, technology related issues could be contained within the *key resources* field of the canvas. However, the feedback from the teams and the evaluation of the resulting data revealed a lack of coverage of central activities – especially those relating to technology development, but also those relating to e.g. legal issues.

From a research rigour perspective, the first prototype was also challenged in a number of ways. The strict list of categories and approaches seemed to be too inflexible and simplistic to represent the process correctly (*theoretical validity*). The use of the business model canvas as a central model in the interface and the limited number of choices is likely to have affected the behaviour of the respondents (*bias)*.

The data was captured using one source (the team's inputs) and one methodology (the interface described) meaning that there is no basis for *triangulating* the results. This can weaken the *descriptive validity* of the study rendering the data collected inapt for describing the phenomenon. To support this weakness, the teams were asked directly whether they thought that the tool provided a precise account of their process (see Figure 33). From this, it was clear that the teams were generally not impressed with the descriptive abilities of the prototype EPR tool.

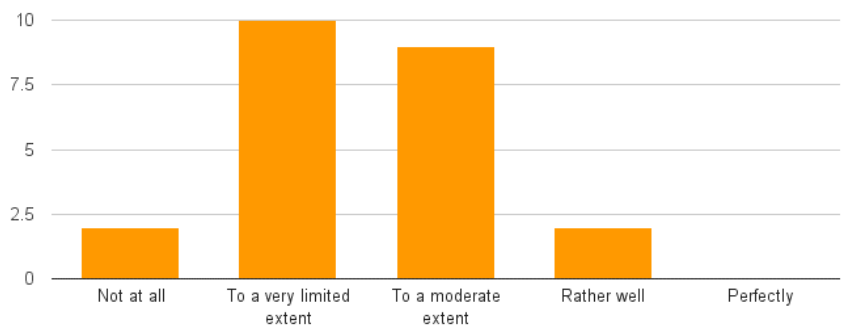

Figure 33: Team feedback on similarity between actual work and the work described in the prototype EPR tool [own]

Another observation was the fact that specific team members were put in charge of updating the data in the EPR tool. Together with the negative feedback on *descriptive validity* just mentioned, there is reason to assume that the *internal generalisability* of the data gathered is also rather poor – i.e. the data gathered cannot be used for descriptions and interpretations of the process of the team as a whole.

The EPR tool did not provide a basis for categorising a given project in terms of a theoretical framework such as Gartner's [Gartner 1985]. This lack of contextual data made it difficult to compare cases resulting in a poor basis for *external generalisation*.

5.3.2 SECOND PROTOTYPE: A TAILOR MADE ONLINE TOOL

Despite the issues with the first prototype, enough positive indications had emerged from its tests to initiate development of a second prototype. The second prototype was supported by the Danish Industry Foundation (www.industriensfond.dk/english/about-the-foundation), which enabled the creation of a far more mature tool.

The second prototype was built on an entirely different technological platform, as it was coded natively in the HTML5 format, which is compatible with browsers on most operating systems, including those on mobile devices. This change in technology meant that the tool could be developed without the limitations of the Google spreadsheet format and that usability could be made a priority.

5.3.2.1 IMPROVING THE USER EXPERIENCE

The main priority of the second prototype was to drastically improve the user experience and usability of the EPR tool. The interface of the tool was designed from scratch based on the feedback from the first prototype. Figure 34 shows the so-called initial "wireframe" of the new version of the EPR tool.

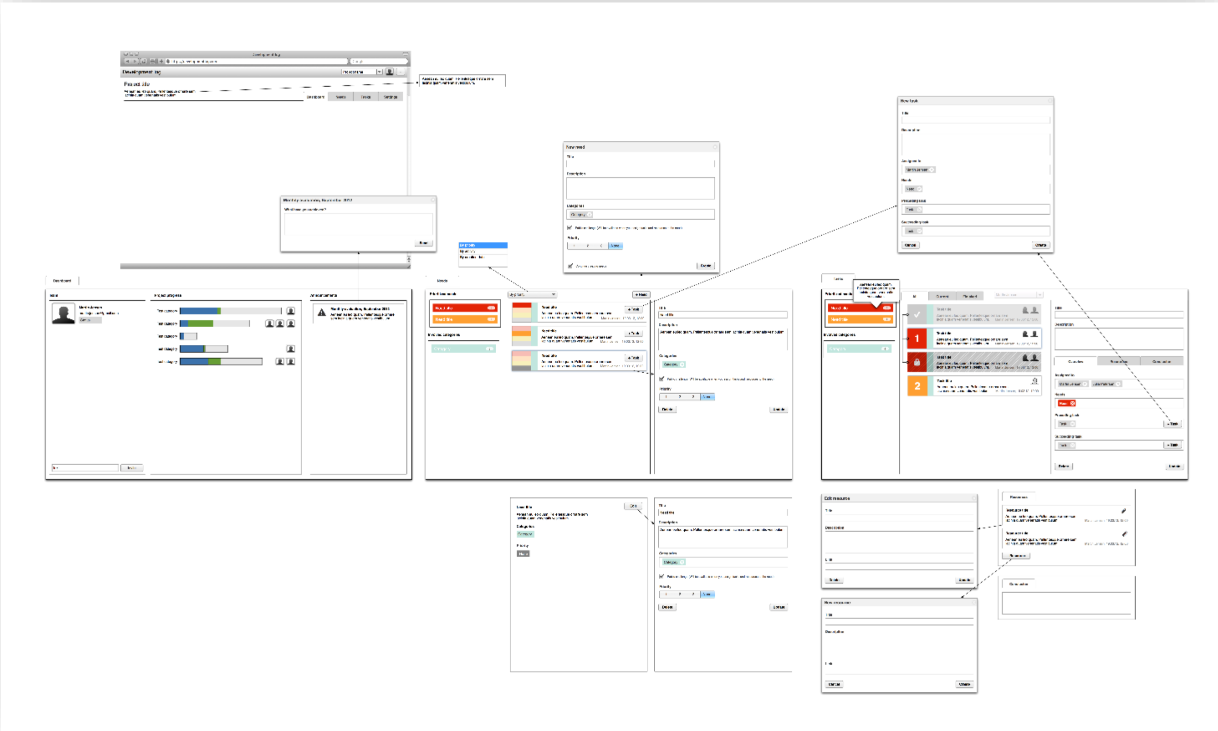

Figure 34: Initial wireframe for new interface [own]

Instead of arriving on a page for adding needs and formulating approaches for addressing these needs, the user arrives on a *dashboard* page, which shows the current team member and the status of activities, within the various categories (more on the categories in the next section).

Also, as a basis for triangulating data, the *dashboard*, features an "achievements" list, where the team is asked to report on progress and challenges independently from the structure defined by the conceptual framework, which is at the core of the rest of the EPR tools features. Each week, the team is prompted to report on achievements when they arrive at the *dashboard* page.

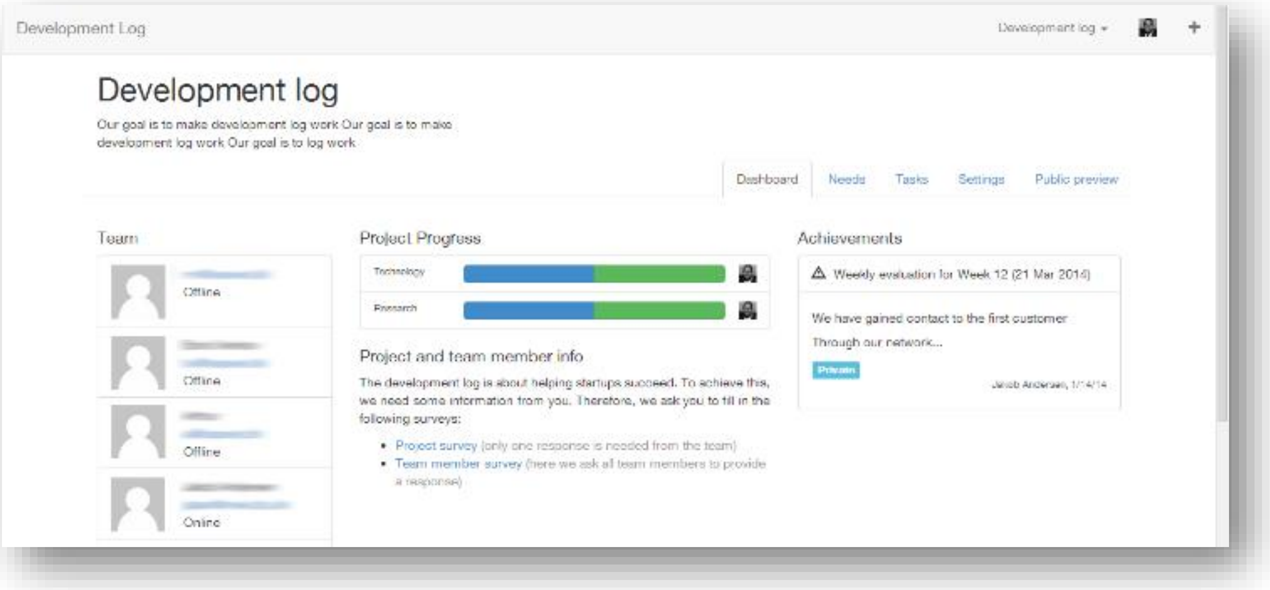

Figure 35: The needs tab (need information right side, filters on the left). [own]

The visual separation of need formulation and prioritisation on one hand, and formulation of approaches, execution notes and conclusions on the other was maintained as two tabs – the *needs*- tab and *tasks tab* respectively. In Figure 36 the contents of the *needs tab* are shown. This tab features a list of needs (middle) to which new needs can quickly be added by clicking the blue *"+need"* button. When a new need is added, a dialogue appears where the user is asked to provide a title, description, a tag (category) and a priority. When the need is added, this informations can be accessed and edited by clicking the need on the list.

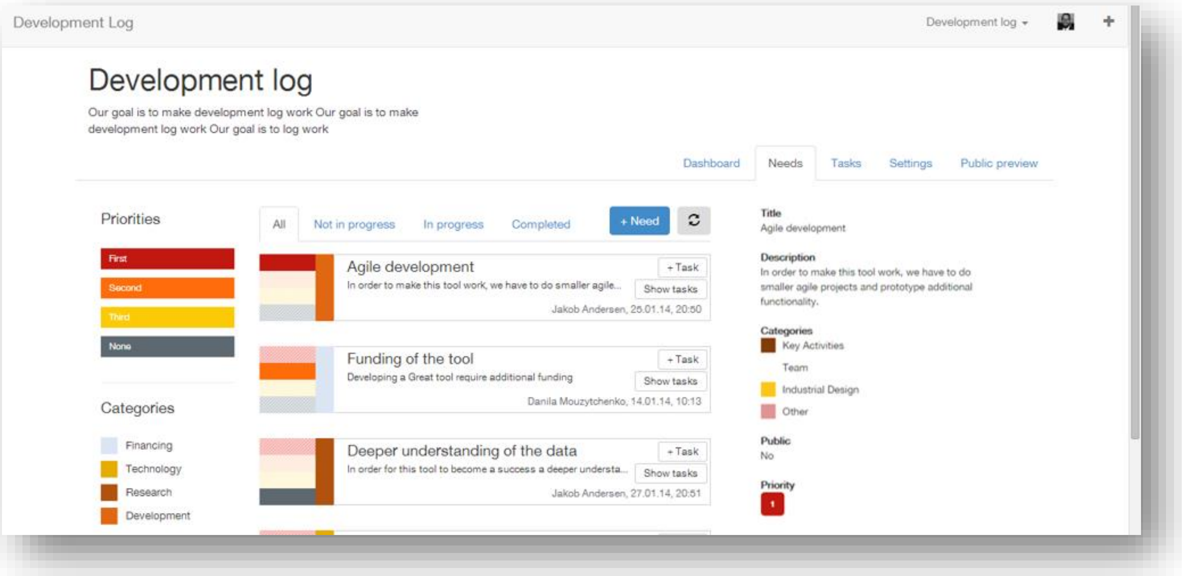

Figure 36: The needs tab (need information right side, filters on the left). [own]

The priority and category are used to help the user gain an overview of the needs list. By clicking a priority or a category on the left hand menu, the list of needs will be filtered to show only needs with that priority and category. Also, at the top of the list, the user can choose between four tabs with a filtered view, based on the needs not being worked on ("*Not* *in progress"*), those being worked on ("*In progress"*) and those that have been addressed ("*Completed"*). These filtering features are a result of the need for an overview expressed by the users of the 1st prototype. The feature makes it easy to e.g. identify high priority needs that are not beeing worked on.

When a need has been created, the user can add tasks based on the need by clicking a button on the need or by going to the *task tab* (see Figure 37). Here, tasks can be made, reviewed and edited in much the same manner as needs are created in the *need tab.* At the middle of the page, the tasks are shown in an order reflecting the priorities of their related needs. A simplified list of prioritised needs is shown on the left side. Clicking a need in this list will filter the task list to show only tasks belonging to that need.

When editing or adding a task, team members can be allocated to work on the task (see Figure 37, right hand side). Whenever the task is assigned to a team member it is considered to be in progress, which. This is visually indicated on the task with two circular arrows. If a conclusion is written for the task, it is considered completed. In that case, a tick mark is used as a visual indication. Again, the tabs at the top of the list can be used to filter the tasks based on status (*not assigned*, *assigned* and *completed*).

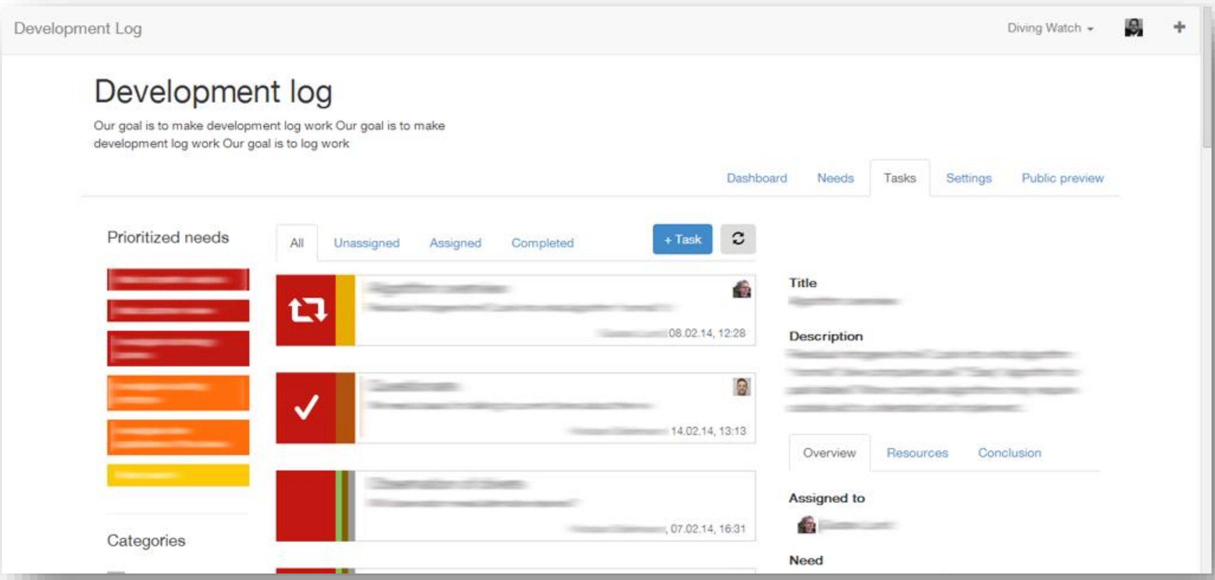

Figure 37: The tasks tab. [own]

The user is likely to use documents of various types to support the task execution. Similarly, when the task is finished, the user will often have a result in the form of a file of some sort – a text document, a CAD model, a link to a report etc. To help the user to solve the task, a convenient feature has been added, which allows the user to link "resources" to the task. This is done by a adding a URL to the document under in the task. Due to the proliferation of cloud tools such as Dropbox (www.dropbox.com) and Google Drive (www.drive.google.com), all types of documents can be linked to the tool in this manner.

5.3.2.2 A NEW, CROWD-SOURCED CATEGORY SYSTEM

The category system of the first prototype was based on the business model canvas, which turned out to be a good, starting point, but insufficient to describe the full array of activities in the process. To address this issue, in-depth literature studies could be conducted, in the hope of revealing a more holistic picture. However, as chapter 2 pointed out, there is little consensus on which conceptual elements should be included in describing the entrepreneurship phenomenon.

Instead, an empirical approach was chosen, based on the notion that entrepreneurial challenges are best understood by listening to what the entrepreneurs are discussing. Specifically, large online entrepreneurship fora were identified as an attractive venue for understanding the issues faced by startups. Typically, a thread in a forum starts with a post stating a problem and a call for solutions. The following posts in the thread provide the responses to the original post and (almost inevitably) digressions in various directions.

Based on this basic structure of a forum thread, a web crawler was created. A web crawler is a piece of software that sends requests to a website in a structured manner and reacts to the responses in a pre-defined manner – in this case by following links to new posts and extracting the first post (the problem statement) in each thread. The open source software "Scrapy" (www.scrapy.org) was used as a web crawler. Figure 38 shows the process of crawling a website to "scrape" the desired data.

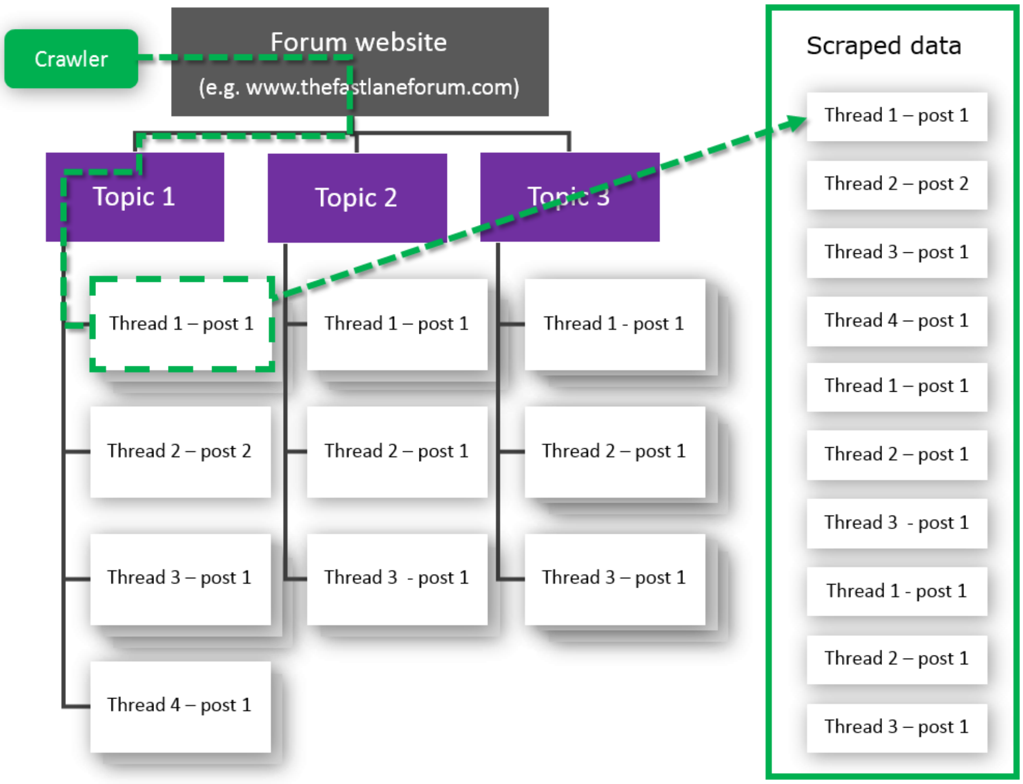

Figure 38: Scraping data from a website [own]

The web crawler was used on two entrepreneurship fora – one American (www.thefastlaneforum.com) and one Danish (www.amino.dk). The "scraped" data was saved to a comma separated format (.csv) and then processed in the natural language processing tool VOS Viewer [Eck & Waltman 2011]. VOS Viewer uses the text corpus to identify central terms and their relation and presents this information in the form of a word cloud. In Figure 39 the word cloud produced based on the scraped data is shown. This word cloud provides an overview of the types of topics, which are being discussed in the first posts of the forum threads.

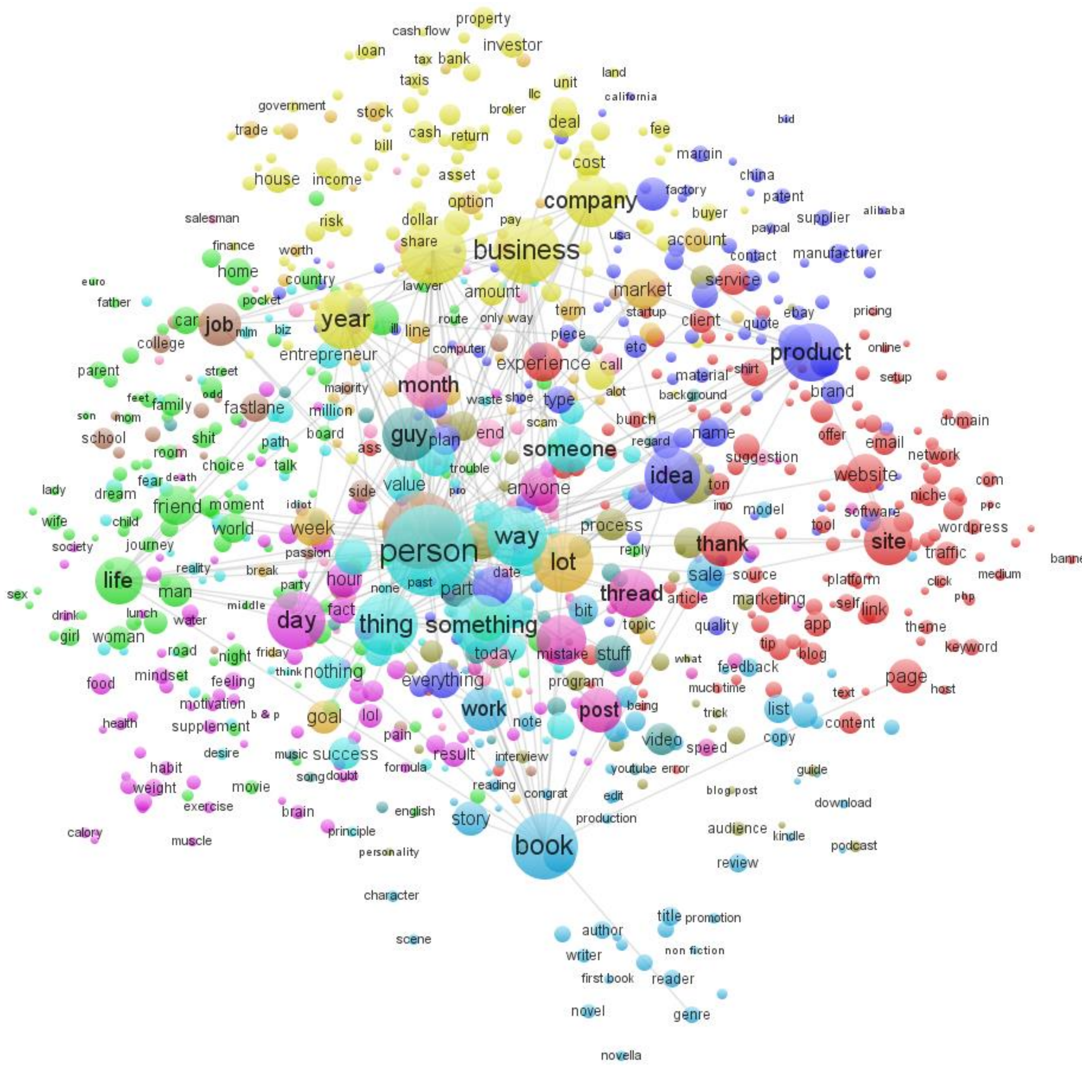

Figure 39: The topics treated in the scraped fora (colours indicate topic clusters) [own, using www.vosviewer.com]

The topics in this word cloud were then compared to the business model categories and topics with poor coverage were given a new category. In addition to these topics, the feedback from the 1st prototype was used as a basis to identify other missing categories. Finally, another analysis was done in VOS Viewer, this time on the diary data produced in the auto-ethnographic study mentioned in chapter 2. Together, these different sources formed the basis for a more exhaustive tagging system (Table 8). To be on the safe side, an *"other"* category was also added, in order to accommodate any topics not covered by the new categories.

Many of these new categories are rather obvious (e.g. *competition* and *legal issues*), but certain surprising categories did emerge; particularly, the existence of needs that relate to the *private life* of the entrepreneur became apparent when surveying the data (green cluster in Figure 39). In the fora analysed, these needs typically pertain to the balance between life as an entrepreneur and married life, social activities, working out, etc. This is a surprising, but relevant topic, which should be included in the tool.

Source	*Category*	*Used in*
From business model canvas (initial categories)	Customer Segments Channels Customer Relationships Value Propositions Key Activities Key Resources Key Partners Revenue Streams Cost Structure	All versions
Topic analysis of scraped data in VOS Viewer www.thefastlaneforum.com and www.amino.dk	Team Legal issues Marketing Private life Idea Financing Competition	All versions after 1st prototype
Student feedback + Topic analysis of diary content in VOS Viewer	Technology Prototyping Research Development Industrial design	All versions after 1st prototype
Other	Other	All versions after 1st prototype

Table 8: The sources of categories in the tool and their relation to various versions.

5.3.2.3 CONTEXTUAL INFORMATION

One of the learnings from the first prototype was that the lack of information for describing and classifying each project and team made it difficult to compare projects and ensure external generalisability.

To address this, the new version of the EPR tool featured two surveys, which should be completed at the initiation of a project.

> *The project survey:* This survey contains questions regarding the *market/sector, customer, partnerships & network, maturity, funding situation, technology* and *team*. The point of this survey was to gain an initial understanding of the venture in terms of the entrepreneurial and technological requirements in Table 6 (page 66). The project survey is done once for each team.3
>
> *The team member survey:* Here, questions regarding each team member's *experience with entrepreneurship/relevant technology/market, their general competencies,* their *commitment to the project* and their *insights into various methods.* The purpose of this survey was to improve the understanding of the team or the *"I"* in Bruyat & Julien's [Bruyat & Julien 2001] theoretical framework. All members in the team were asked to fill in this survey.

By covering many of the conceptual elements in entrepreneurship research (e.g. [Gartner 1985; Bruyat & Julien 2001]) as well as elements critical to the understanding of technological risk, the two surveys constitute a marked improvement in terms of support for *external generalisability.*

5.3.2.4 A NEW STRUCTURE

The overly rigid format of the first prototype led to a poor *descriptive validity* and the inflexible application of the conceptual framework was likely to *bias* the phenomenon to an unacceptable degree. Instead of enforcing strict, predefined options, the new version of the EPR tool was designed to rely on natural language (written) inputs, thus greatly increasing the flexibility of the tool as well as its *explorative* capabilities.

Table 9 is a simplified version of the data structure used in the second prototype. On the left the different classes of data are shown - *project*, *need and task* – and below each of these, the types of data being logged when the team uses the EPR tool. In the header of each class, the links to other elements are indicated with ticks: For instance, a *need* is always connected to a project and a *category.* A *task* is always connected to a particular *need*, other *tasks* (preceding/succeeding), *categories* and *team members.* These linkages ensures that a context is always provided for formulated tasks and their outputs. This is to support the requirement that the process should be described in terms of the transformation of inputs into outputs (req R6.1 and Figure 18, (page 57).

	Linked to ...					***Log frequency***		***Type***
	Project	**Need**	**Task**	**Category**	**Team member**	**At project start**	**When changed**	
Project	✓					✓		
Mission						✓		Description (plain text)
Team members						✓		Finite set of names
Project evaluation							✓	Description (plain text)
Need	✓			✓			✓	
Description							✓	Description (plain text)
Priority							✓	Integer (0-3)
Task		✓	✓	✓	✓		✓	
Description							✓	Description (plain text)
Status							✓	Finite set of categories
Resources (links)							✓	URL to resource
Conclusion							✓	Description (plain text)

Table 9: The data structure (simplified) of the 2nd prototype

Table 9 also shows when a given piece of data is logged - e.g. *at project start* or *when changed*. If the latter is the case, a new version will be created for the data entry. Old revisions are kept.

To facilitate *triangulation* of data, the structure now features an open-ended *project evaluation* class, which allows the team to report on activities under without having to comply with the "*need-task*" format.

5.3.2.5 TESTING THE SECOND PROTOTYPE

Again, the second prototype was tested in a project-based tech startup course. This time 10 projects with 4-5 engineering students used the EPR tool over a 13-week period. Alongside this isolated test, the tool was launched on a website for anyone to use. Due to this online availability, the 10 projects coming from the course were supplemented by approximately 26 projects of unknown origin.

5.3.2.6 LEARNINGS FROM THE SECOND PROTOTYPE

Despite being a significant improvement from the initial prototype, the second generation of the EPR tool revealed a number of areas in need of further improvement. Generally, the investment in improving usability seemed to have paid off and the intensity of use was far beyond what was seen for the first version.

However, the users were still not fully satisfied with the usability of the tool, which affected the quality of the results. Despite the introduction of a new interface and multiple filter options, the *need*- and *task list* quickly became very elaborate and the teams struggled in maintaining an overview. As consequence of this, the teams often assigned a *specialist* to update the project data in the EPR tool and maintain an overview. In this way, it became more of an accounting tool than a support tool. This indicated that the issues concerning *internal generalisability* were still a concern.

One other root cause for this single-user tendency was the fact that the platform did not provide facilities for intra-group communications. This meant that the team's communications tended to happen on other platforms such as Facebook or Podio. When the teams got into the habit of intensively using these other platforms, having to use another platform for need and task management became a hassle rather than a help.

Finally, despite seeing an increased level of activity, the EPR tool was not used to a degree where one could credibly argue that the short-duration *micro strategies* (relating to req. R6.4) of the team members were being described other than through questionable inductive steps.

5.3.3 THIRD AND FINAL VERSION: VISUALISATION AND COMMUNICATION AS PRIORITIES

The third and current version (at the time of writing) builds on the learnings from the 2nd prototype. The development of this version was supported by the Young Enterprise Foundation (www.ffe-ye.dk). This version of the EPR tool has been given the name "The Development Log" and it can be found in its current version on the tool's own website http://developmentlog.rubix.dk.

Along with the major changes and additions described below, a number of adjustments were made to the interface, to improve usability.

5.3.3.1 PROVIDING AN OVERVIEW FOR AN ENTIRE TEAM

In parallel with the development of the EPR tool itself, a number of ideas were tested to visualise the data produced by the tool. This effort was very much inspired by [Miles et al. 2014]'s recommendation, that qualitative researchers should continuously explore their data by creating visual representations.

In Figure 40, an initial example of a process visualisation is shown. This visualisation is based on data coming from the first prototype and it shows the *needs, tasks* and conclusions as connected nodes on a timeline (going from left to right).

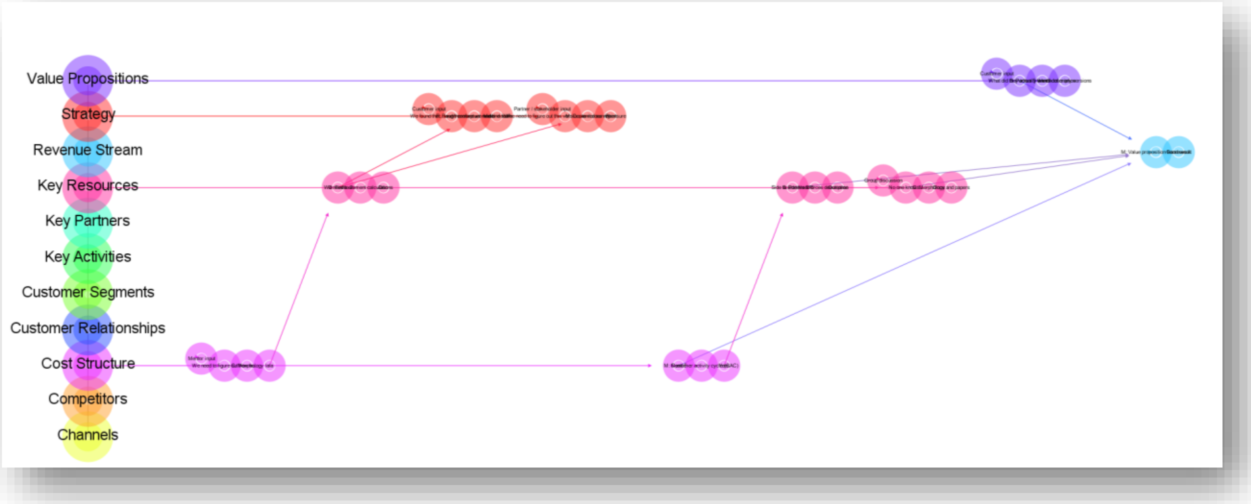

Figure 40: Early visualisation of data from EPR tool [own]

As described, the category system and general structure of the EPR tool were changed markedly for the next version of the (2nd prototype). Based on the new structure, a new process visualisation was developed. The updated visualisation is shown in Figure 41 - note that coloured boxes have been added to explain the structure of the network. Again, a timeline is used (left to right), but this time the nodes are divided based on type (*needs*, *tasks*, *conclusions*, *resources*, *achievements* and *admin, which includes categories and team members*) in the vertical direction. This representation has been built based on the HTML5 language, meaning that it can be viewed by anyone in a web browser. This also means that the representation is interactive in that the user can interact with the nodes by clicking them. This filters the view showing only the clicked node, as well as the other nodes to which it is connected.

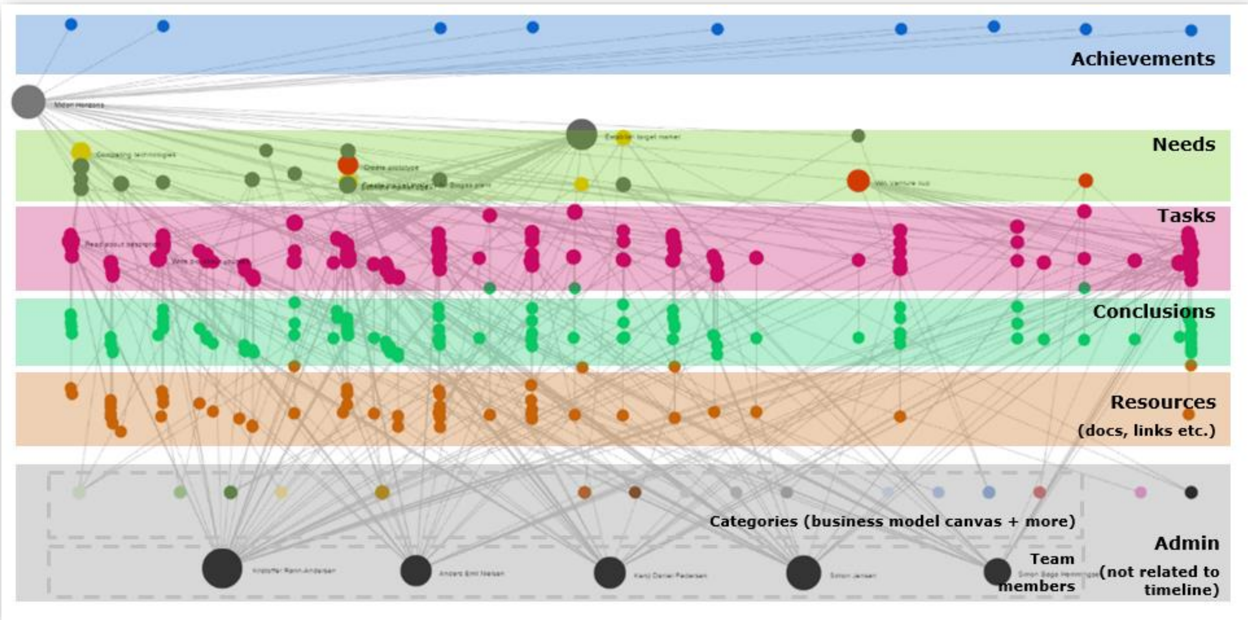

Figure 41: The new data visualisation format (coloured boxes are added to explain components of network) [own]

This second visualisation format has been used extensively by the author in gaining a qualitative overview of project contents. Seeing that one of the major issues reported by the users of the second prototype was a lack of overview, it was decided that the network visualisation of the data should be integrated in the new version of the EPR tool– see Figure 42, where the new *"Network"* tab's contents are shown.

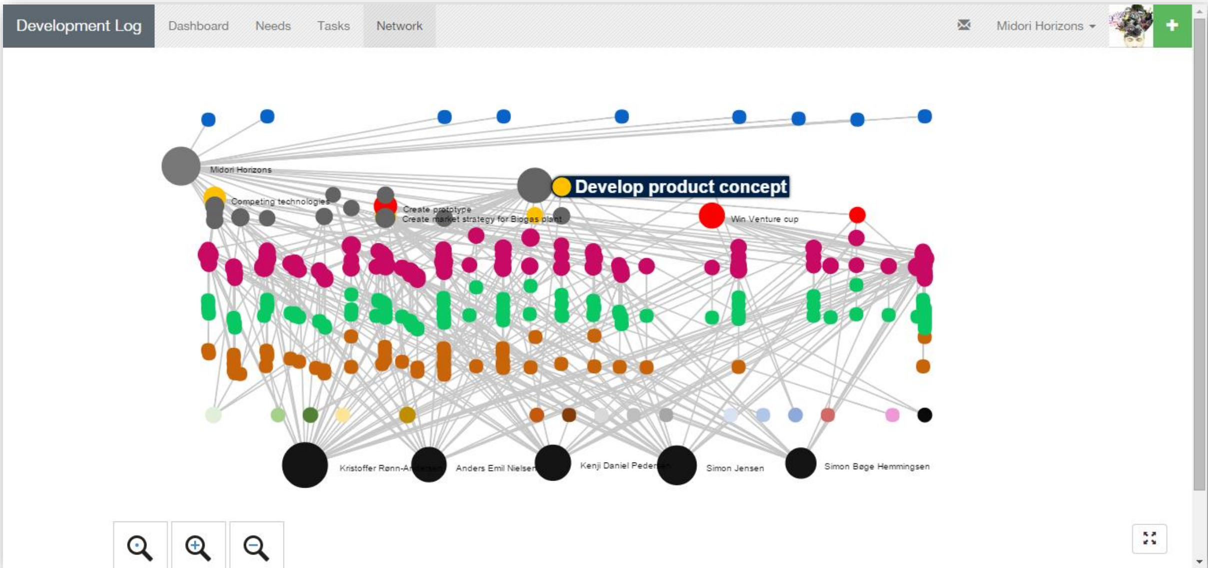

Figure 42: The integrated network representation in the EPR tool [own]

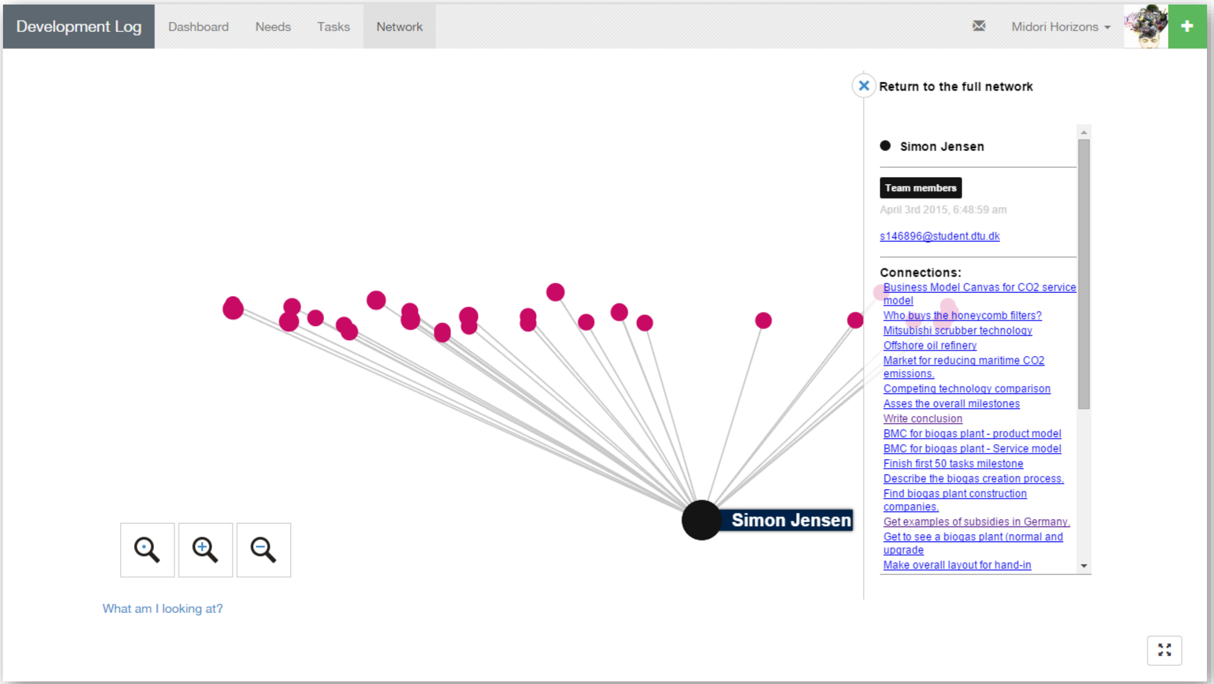

Figure 43: The filtered view with node details (right pane) appearing when a node is clicked – in this case a team member node. [own]

With this network representation integrated, team members can quickly and intuitively navigate the contents of the database. By clicking a node for a specific team member, the *task*s assigned to this person are shown (see example below in Figure 43). If a *category* node is clicked, the *needs* related to that category will be shown. In this way, the network representation provides a basis for finding relevant information in the database.

1.1.1.6 EXAMPLE OF PROJECT: DREDGING SHIELD TECHNOLOGY

Preliminary notes: *In this case box, the network representation is used as a basis for exploring the Dredging Shield project. For confidentiality reasons, specific references to technolology, organisations and persons have been removed. The project explored is part of a university course (see page 132) and it has been chosen because it has a limited amount of data points, making it possible for the reader to follow the description.*

About the project and technology: *This team deals with a technology, which greatly reduces the spread of sediment when dumping material from dredging activities (under-sea excavation). The suspension of sediment particles in the water column can lead to many negative environmental effects and the dumping of dredging materials is therefore a field governed by strict legal requirements. This limits the practical and financial feasibility of dredging activities. The full network representation of the project's data is shown in Figure 44.*

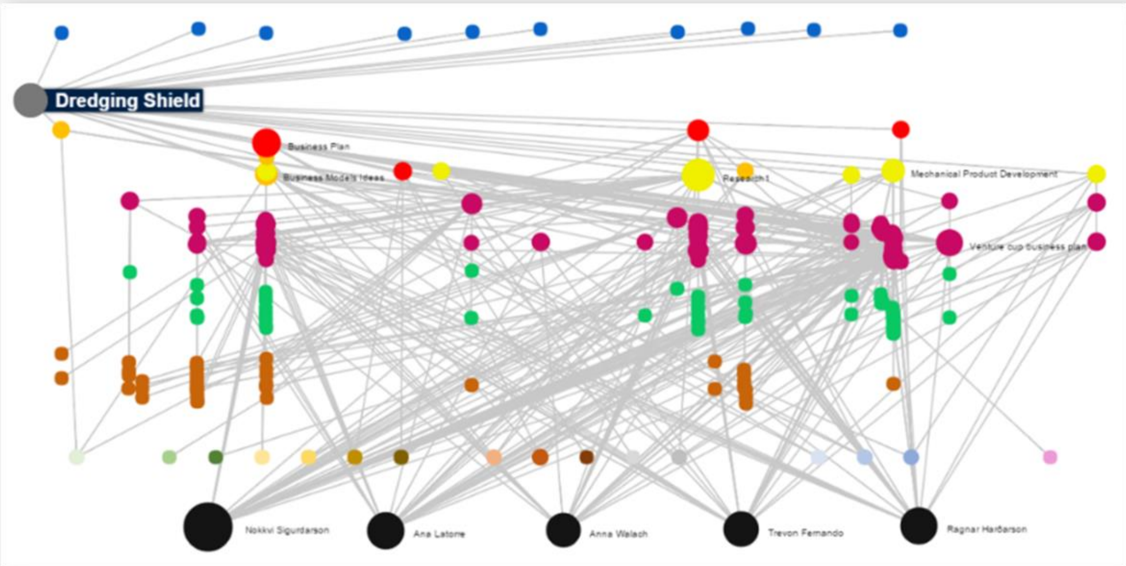

Figure 44: The full network for the dredging shield project [own]

Table 10 shows a number of statements recorded in the team's achievements (top row of blue nodes) in Figure 44.The achievements give a good general overview of the activities of the team. From the statements listed, it is clear that the initial focus of the team was on understanding the technology and the processes of dredging and dumping. The team adopts a proactive strategy where they try to get in contact with as many relevant stakeholders as possible. Also, half way into the recorded process (day 47), the team mentions an effort to raise capital for prototyping. In the second part of the project, the team manages to establish a contact with a relevant national authority on coastal protection, which apparently leads to the identification of a "new spin out idea". Towards the end of the captured data, the team is increasingly focused on the formal requirements from the course it is part of.

Date	Day #	Entry (achievements)
01-02-2015	0	**[Project start date]**
02-02-2015	1	*"Today we have discussed the different applications of the given invention. On one hand is the effectiveness of the process, making it cheaper."*
27-02-2015	26	*"The last week we were working on finding contacts from industry to learn more about real-life process workflow and costs connected to the dumping"*
13-03-2015	40	*"In last two weeks, we've gathered a lot of contacts: dredging company, environmental agency, [Danish port] and we were even assigned with a mentor!... We started work in three fields: detailed business model, design of the product and acquiring all necessary information from our contacts (mostly regards the design and detailed business model)."*
20-03-2015	47	*Funding: We developed a great application to get some funds and have the change to go further with the prototyping.* *Contacts: still working on it, we reschedule a meeting with one of our contacts, and got some responses of dredging companies and environmental agencies."*
27-03-2015	54	*"We also got in touch with a contact in [Danish coastal authority]. She gave us a big insight about the coastal protection process. After talking with her we had new spin of out idea."*
10-04-2015	68	*"We find out what were the international rules and regulation for dumping material. We also sketched our prototype"*
17-04-2015	75	*"We came up with a name for the company and also made some designs for the logo of the company. We have been working on the Business plan as well, we are making our business plan more solid by making sure the facts and the numbers are accurate."*
03-05-2015	91	*"With the deadline right around the corner our group worked hard on realizing and finalizing the Venture Cup business plan."* *With assistance from our mentor the business plan took shape, making sure the focus of the group got across to the reader."*

Table 10: Statements taken from achievements reported by team.

Date	Day #	Priority	Entry (need)
01-02-2015	0	N/A	**[Project start date]**
06-02-2015	5	2	***Title: "Financial gains" (priority: 2)*** *"In order for this to be a valid project there needs to be a monetary value for companies to invest in or buy our product"*
27-02-2015	26	1	***Title: "Business Plan"(priority: 1)*** *"We need to have a business plan."*
27-02-2015	26	2	***Title: "Definition of MVP" (priority: 2)*** *"We need definition of Minimum Viable Product."*
27-02-2015	26	3	***Title: "Meet the inventor" (priority: 3)*** *"First meeting with inventor."*
27-02-2015	26	2	***Title: "Business Models Ideas" (priority: 2)*** *"We need to prepare different business models ideas."*
13-03-2015	40	1	***Title: "Product Specification" (priority: 1)*** *"Product Specification"*
17-03-2015	44	3	***Title: "Visualization" (priority: 3)*** *"We need to be able to get our idea across easily. Images speak louder than words so a good illustration will do a lot of work for us"*
12-04-2015	70	1	***Title: "Industrial contacts" (priority: 1)*** *"Contact with potential clients and users is essential!"*
12-04-2015	70	3	***Title: "Research" (priority: 3)*** *"We need knowledge regarding this subject. Any and all relevant information should be linked here"*
17-04-2015	75	2	***Title: "Prototyping" (priority: 2)*** *"The design of a prototype is required to provide proof of functionality."*
28-04-2015	86	3	***Title: "Graphic content for process exam"(priority: 3)*** *"This is the presentations, and graphic elements we need to express or corporative content"*
02-05-2015	90	3	***Title: "Mechanical product development" (priority: 3)*** *"The mechanisms and solutions that will allow the overall functionality need to be developed."*
03-05-2015	91	1	***Title: "Investor presentation" (priority: 1)*** *"26th may there will be an invitational gathering of investors within this course."*
23-05-2015	111	2	***Title: "Final pitch" (priority: 2)*** *"The final pitch the 26th."*

Table 11: Needs formulated by dredging team - dates indicate last update and the priority column shows the priority at this last update.

When looking at the needs formulated by the team, the overall topics mentioned in the achievements are generally mirrored. Table 11 shows the needs formulated by the team. Each of these needs has a number of associated tasks, which can be inspected in turn. As the "Industrial contacts" need seems to have been an important one for the team, this is explored further (see Figure 45).

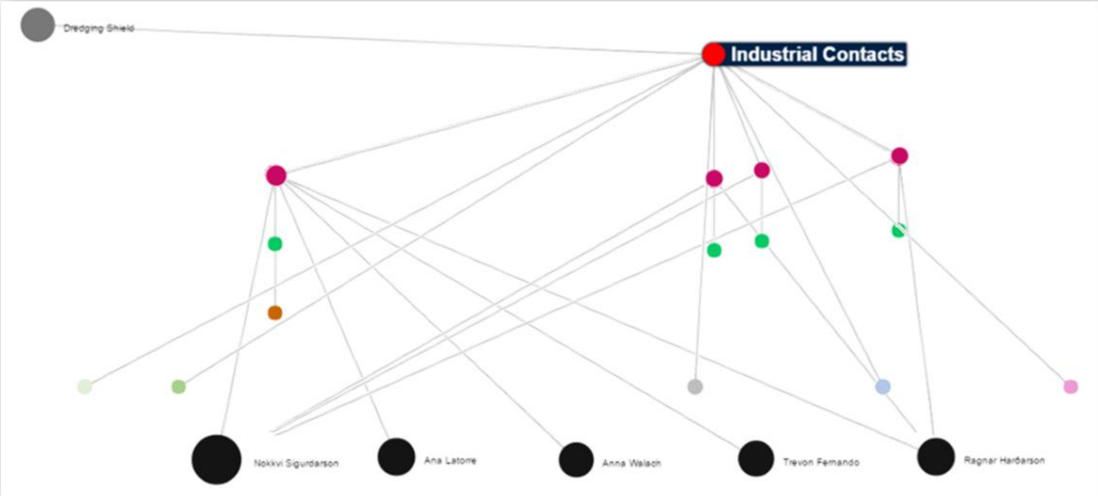

Figure 45: The tasks (purple), conclusions (green) and resources (brown) related to the "Industrial contacts" need. (related categories and team members are also shown) [own]

From the figure, it is apparent, that one team member (the large black node to the bottom left) is related to all tasks, indicating that this member has had an important role in executing the tasks.

Date	Day #	Entry (task)	Conclusion
01-02-2015	0	**Project start date**	N/A
27-02-2015	26	***Title: "Find appropriate contacts"*** *"Each member should find at least two contacts from the industry."*	*"On our meeting on Friday, 20.02 we exchanged the informations and decided to contact relevant person and companies. There is appropriate document with in in google drive."*
12-04-2015	70	***Title: "List of contacts we are in touch"*** *"We need all the list of contacts that we are in touch with at the moment."*	*"We made appropriate list on google drive and we update it, whenever new contact appears."*
17-04-2015	75	***Title: "Contact consulting companies."*** *"We need to contact consulting, civil engineering companies that may help us establish connection between coastal protection/building companies and dumping projects."*	*"Contact was gained with leading consultants in the offshore and coastal sector, mainly through [name of Danish engineering consultancy], who advised us on how dredging projects are planned, on coastal engineering and on offshore construction. As a result, the core value proposition of the product has shifted."*
01-05-2015	89	***Title: "Contact relevant companies and people."*** *"We should try to get information about costs and process workflow (especially the practical part)."*	*"Contact has been made with [name of Danish engineering consultancy], [name of large dredging company], and the Danish coastal and environmental authorities. Knowledge on legislation, work processes and best practice in offshore construction projects has been gathered, and the business model and product properties have changed as a result."*

Table 12: Contents of tasks related to the need "Industrial contacts".

The four task nodes shown contain descriptions and conclusions, which can be seen in Table 12. The task contents reveal the team's initial strategy, which is to initially find as many industry contacts as possible by individually coming up with at least two potential contacts. These contacts are recorder in a list, which is later updated to reflect the active contacts of the team. Later in the project (day 75), engineering consultancies are identified as a potential sources of relevant contacts in the industry. Toward the end of the recorded data (day 89), the team seems to have found a number of interesting contacts in engineering consultancies, in dredging companies and in relevant authorities. Based on this, they claim to have gained knowledge on several important areas, which has led to a revision of the business model.

5.3.3.2 TEAM COMMUNICATIONS SUPPORT

Two further crucial learnings from the second prototype were the lack of insights into the shorter-term cognitive strategies of the entrepreneurs (relating to req. R6.4) and the tendency of the teams to rely on other platforms for communication. It was realised that both of these issues could be addressed by adding communication features – especially if this feature maintained a link between the conversation and the other elements in the data structure.

In Figure 46, an example of a *conversation* window is shown. This window has appeared by first clicking "chat" on the element (in this case a *need*). This creates a pop-up, where existing conversations relating to this need are visible and where new conversations can be created. The conversation window shown appears when "new conversation" is clicked.

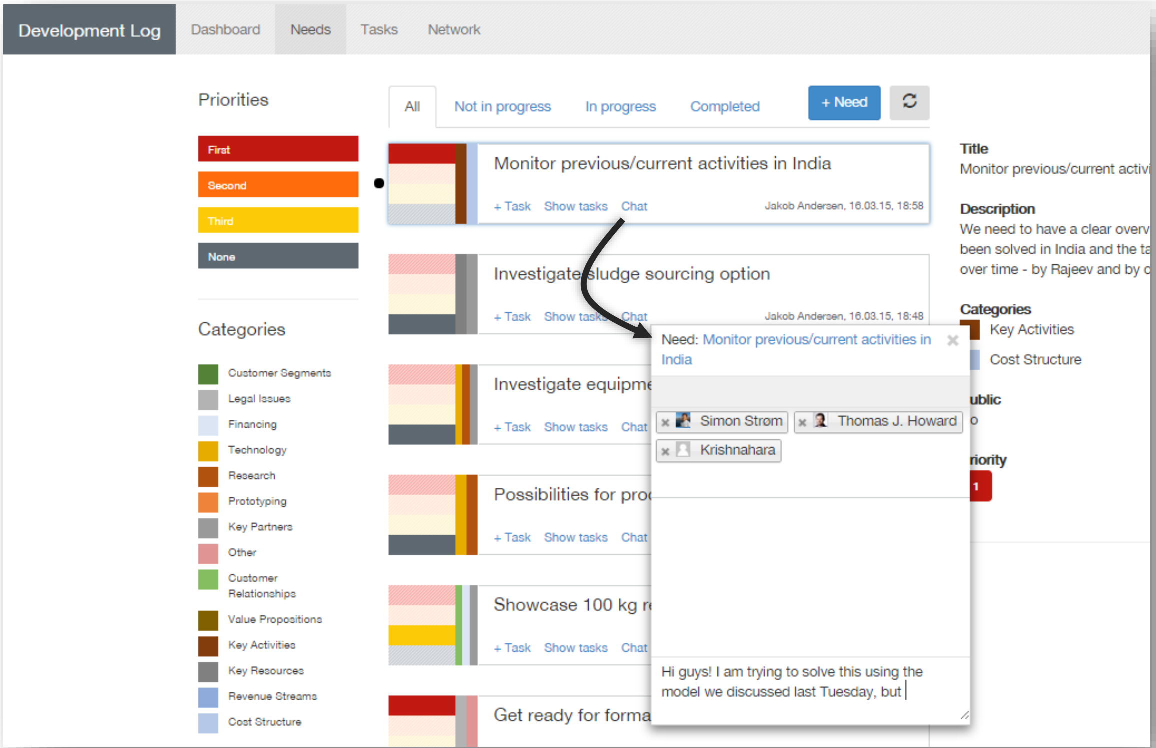

Figure 46: Starting a conversation [own]

As can be seen in the header of the conversation window, the conversation is then linked to this particular need. When added to the conversation, other users will get a notification (a letter icon in the top menu bar). This icon will take the user to the new conversation, where the text in the header works as a link to the *task* or *need* in mention. In Table 13, the relation between the new chat function to the general data structure is shown.

	Linked to ...					Log frequency		Type
	Project	**Need**	**Task**	**Category**	**Team member**	**At project start**	**When changed**	
Conversation	✓	✓	✓		✓		✓	
Chat message					✓		✓	Description (plain text)

Table 13: The link between the conversation data and the remaining data structure.

5.3.3.3 TESTING THE CURRENT VERSION

The current version of the EPR tool was tested in the same manner as the two prototypes: An entrepreneurship course dealing with advanced technology. In this test, 21 teams of the same type and composition as in previous tests. At the conclusion of this test period, the EPR tool had been available online for 18 months and 197 projects were now registered online. Most of these (around 75%) are unrelated to the tests described and the work of the author. These 197 projects include 593 unique users.

Of the 197 teams working with the support of the EPR tool, 63 have responded to the *project survey* mentioned earlier and 146 users have responded to the *team member survey*. The resulting data will be treated below in section 6.2.1 on page 126.

5.3.3.4 LEARNINGS FROM THE CURRENT VERSION

As was the case with the previous versions of the EPR tool, the users again provided feedback concerning minor shortcomings and bugs in the user interface. However, most importantly, at this point, it had become clear that it was not obvious to the users how the EPR tool should be used to support the process. The implicit assumption had been that the alignment between the practice of the entrepreneur and the functionality of the tool (rooted in the *conceptual framework*) would be a sufficient basis for the entrepreneur in intuitively understanding how the tool should be used.

This makes it clear that the features of the EPR tool and the way in which they support the process should be made explicit to the user. An increased level of instruction is undesirable, as it can effectively be seen as an introduction of *bias*. Also, the lack of lack of intuitive use, could be an indication that the underlying *conceptual framework* is not perfectly matched to the phenomenon, meaning that the *theoretical validity* could be a concern. Conversely, one could argue that any software tool of some complexity needs to be introduced in more detail than has been the case here and that the cognitive underpinnings are unlikely to be self-explanatory.

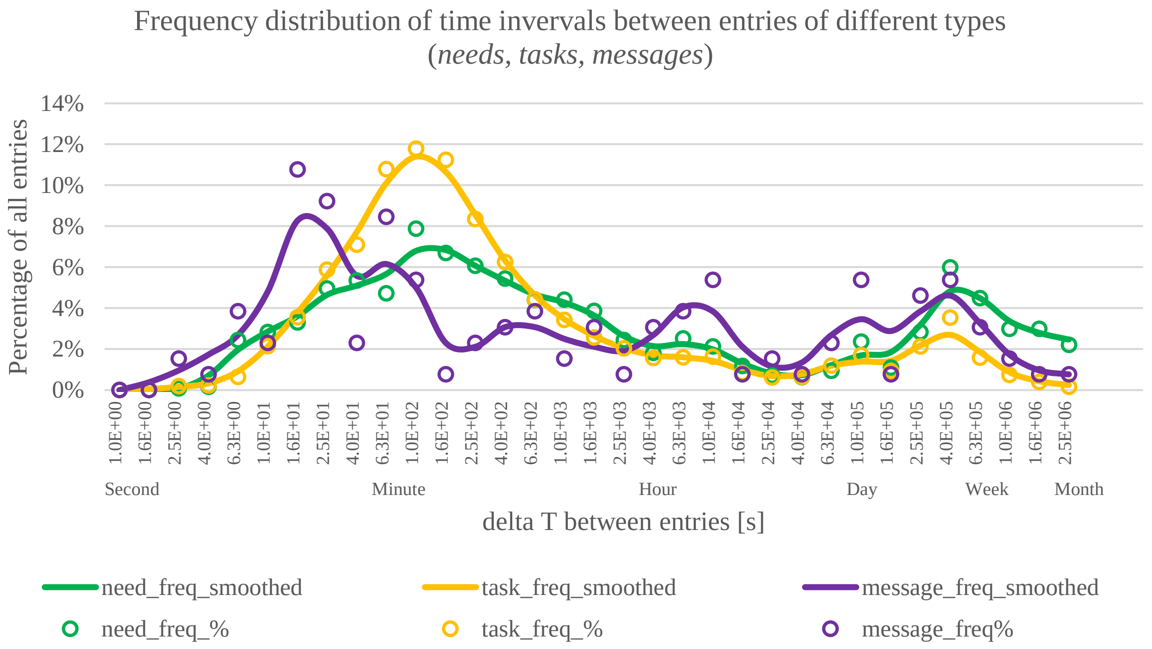

Figure 47: Frequency for time intervals between entries of *needs, tasks and conversations* [own]

On a related note, the new *conversation* feature was not widely adopted by the users. As with the other elements, the reason for this is thought be due to a lack of introduction. As is obvious from Figure 46, the visual presence of the *conversation* feature is limited. Despite a rather slow start to the use of the feature, the initial usage statistics seem promising. As stated above, the aim of the feature was two-fold; to migrate team communications from other platforms (e.g. Facebook) and to improve the temporal resolution of the data collected. The first aim has yet to be realised, but the time resolution (delta T between updates) is found to be markedly better than the resolution for *needs* and *tasks.* A comparison of the frequency distribution of time intervals can be seen in Figure 47. From the figure, it is clear that although the *conversation* feature produces data at very varied time intervals, it also provides information at shorter time intervals than the *needs* and *task* features.

This figure also has another interesting feature; at 2,5E5-6,5E5 second interval range, all three curves show a local peak. This interval corresponds to approximately the 3 and 4 days between group sessions in the course where the EPR tool was tested, indicating that there was a tendency for the project teams to update contents when they met for group sessions.

The time between inputs is an indicator of the detail of the data in the database. Another measure is the total number of data points for each project. Figure 48 shows the top 50 projects in terms of data points (divided on *need*-, *task*- and *resource revisions*). From this, it is clear that the amount of data points per project varies quite significantly. As an added note, the majority of the projects with a high number of data points are related to the course, which has been mentioned several times in relation to the testing of various versions of the EPR tool. This high intensity of use can be attributed to the fact that the teams were required to use the tool and the fact that the teams were given a general introduction and support on its use.

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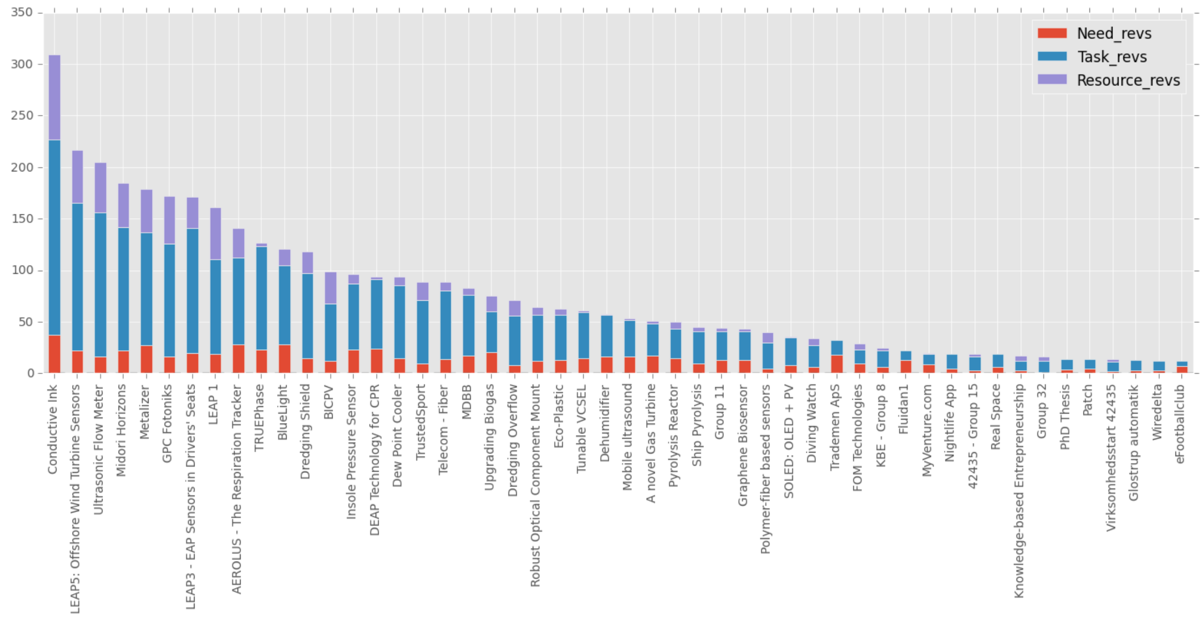


Figure 48: Projects sorted by number of data points [own]

5.4 INTEPRETING LARGE AMOUNTS OF QUALITATIVE DATA

As briefly mentioned in the description of the development of the current version of the EPR tool, there was a parallel development track concerning new ways of analysing and visualising the data produced by the tool. This track has been very much inspired by [Miles et al. 2014], whose approach to qualitative data analysis involves the following steps:

4. *Data condensation*
5. *Data display*
6. *Conclusion drawing / verification*

Data condensation involves transforming data into a manageable format by selecting certain bits of, focusing on, abstracting from or transforming the initial data. The process of *condensation* is very much related to the *descriptive validity* term, as poor decisions in condensation can lead to a poor descriptive account of the phenomenon.

Data display is related to how the data is communicated to the researcher in a way that supports the 3rd step – *conclusion drawing / verification.* Text is a traditional way to display data, but as the amount of data, it becomes an inefficient format. Also, text formats such as field notes often lack consistent structure. Miles, Huberman & Saldaña *"... urge a more inventive, self-conscious, and iterative stance toward [display] generation and use"* [Miles et al. 2014].

The last step, *conclusion drawing / verification* relates to the *meaning* of the observed data in terms of patterns, explanations, causal flows and propositions. This is where the researcher builds or verifies theory.

Together with data collection, these three elements form the basis for an interactive model for data analysis (see Figure 49).

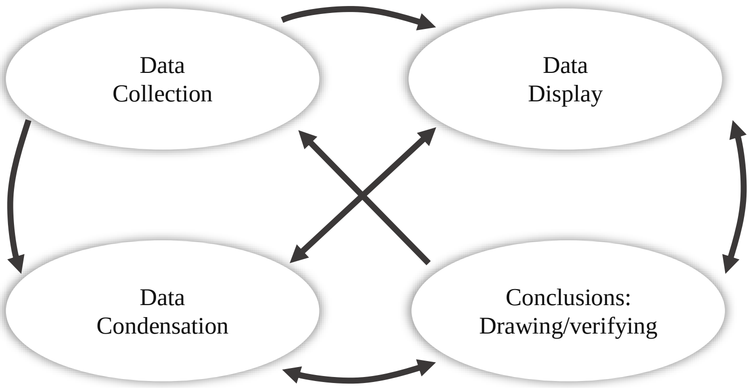


Figure 49: Components of Data Analysis: Interactive Model [Miles et al. 2014]

When developing the EPR tool for entrepreneurship processes, it quickly became apparent that if the tool worked, it would be able to capture a large amount of data very quickly. In this light, the network visualisation shown earlier is a method for enabling the researcher to quickly gain an overview of the process at hand. Although a marked improvement over having to scour the EPR tool's database, this method is only feasible for qualitatively analysing 10-20 projects at a time. Beyond that, the method becomes inefficient. As a frame of reference, tool's database contained 197 projects at the time of writing.

Another method which could be relevant is that of *grounded theory* [Charmaz 2006] where a corpus of text data is surveyed and emerging themes identified and given a code. These codes can then be used for tagging new pieces of data, while at the same time allowing for new concepts to emerge (and new codes). There is certainly sense in applying grounded theory to the qualitative data captured with the EPR tool, but again, the problem of scale emerges.

5.4.1 MACHINE LEARNING AND NATURAL LANGUAGE PROCESSING

To enable analysis of large amounts of qualitative data inspiration was found in Hansen et al's effort to populate an ontology for product development process by using an automated method for gathering data from bibliographic materials [Hansen et al. 2001]. As a support for this undertaking, the areas of *natural language processing* (NLP) and *machine learning* were explored. NLP is the use of computers for analysing large amounts of qualitative data (text) [Sarawagi 2007; Bird et al. 2009]. NLP relies on the transformation of text data into a vectorised data formats (*tokenisation*), which can be treated by computers. These vector formats can then be used in a number of ways. One avenue is to use *machine learning* (ML) *techniques* (related to *artificial intelligence*), where various statistical methods are used for identifying interesting features in the data. ML can also be used for "training" computers to recognise certain semantic patterns [Cristianini 2002; Conway & White 2012; Segaran 2007]. Generally, two types of machine learning exist:

> *Supervised learning:* in this type of learning, data being analysed is already tagged, meaning that the role of the statistical method is to identify components (e.g. certain words) or patterns (e.g. sentences), which are statistically correlated with a given tag. For instance, the word "*sandwich"* will tend to appear as a feature in the parts of data tagged with "*lunch*". In advanced machine learning methods, the relation between the features (*words, semantic structures etc.*) and the tag can be more or less complex. For instance, Naïve Bayesian methods provide a high degree of transparency and the features behind each tag can easily be explored and understood. Other methods such

as *neural networks* or *support vector machines* are far more opaque in the way tags are predicted, but more precise.

Unsupervised learning: In unsupervised learning, the tags are not known beforehand and instead the statistical method looks for patterns in the data – e.g. words that are often used in the same sentence. In some methods, these patterns are used for calculating the degree of affinity or proximities between entries in the dataset. This can then be used for clustering terms together and identifying interesting topics. The VOS Viewer software [Eck & Waltman 2011], which has been used several times herein, uses such an unsupervised clustering method. Unsupervised methods provide a good way to explore an unknown phenomenon by way of qualitative data, without the requirement for a pre-existing theoretical framework.

5.4.2 EXPERIMENTING WITH MACHINE LEARNING AND NATURAL LANGUAGE PROCESSING

Inspired by protocol analysis techniques [Gero & McNeill 1998; Stempfle & Badke-schaub 2002], grounded theory and the computational techniques listed above (NLP & ML), a number of experiments were conducted to see if elements from each of these fields could be merged in a method for making interpretations of large qualitative datasets.

Various attempts have been made with regard to tracking theoretical concepts in the dataset. One challenge in this regard has been to find a sound way of linking *theoretical concepts* to the observed data – i.e. the *construct validity*. As a basis for understanding this challenge, a simple model is provided for relations between *theories*, *methods* and *heuristics* (see Figure 50).

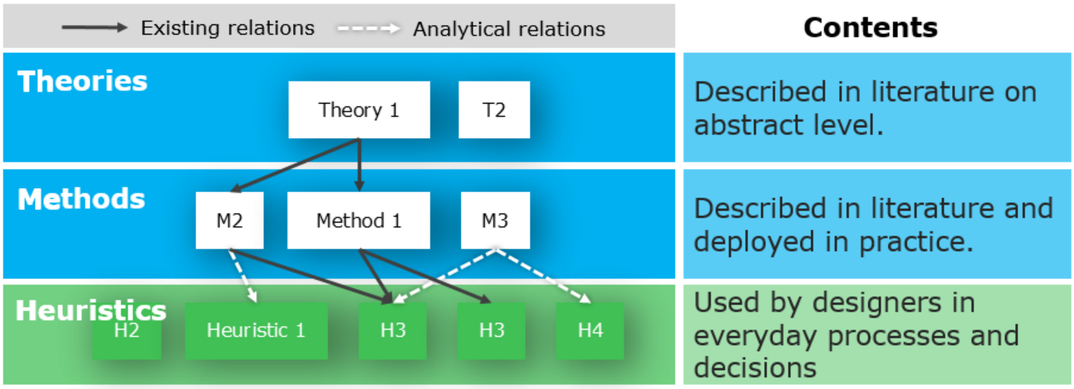


Figure 50: A simple model for the relation between theories, methods and heuristics [own]

A *theory* describes a phenomenon in general terms, but is normally not normative in nature. *Methods* are normative in nature and can be derived from theories, but more often than not, they constitute the highest level of abstraction. At a lower level of abstraction, heuristics can be seen as sub-components or simplified versions of methods used in practice by the participant. Also, the heuristic is formulated in simple, practical terms. As with *methods*, *heuristics* can exist in isolation. For a given *theory*, it should be possible to formulate methods. Similarly, for a given *method*, it should be possible to derive *heuristics*.

Sarasvathy's Effectuation concept [Sarasvathy 2008] is a good example of a theory, from which a method has been derived, which has in turn been the basis for the derivation of various *heuristics* (see the five *effectuation principles* in section 3.2.3, page 34).

The reason why this taxonomy is introduced is that the database was found to reveal few explicit references to *theories*. Although more prevalent, *methods* were similarly difficult to identify in the data. Seeing that they are often expressed in simple, practical terms, *heuristics* turned out to be much easier to track in the data using NLP and ML.

The next question then becomes what the unit of analysis should be; whole paragraphs of text, sentences or single words. Paragraphs can provide a very nuanced account of the process of the team, but paragraphs were found to contain references to many different topics and heuristics. At the other extreme, words (including sequences of 2-3 words) can be directly related to a heuristic. One can, for instance, safely assume that the identification of the combination "*patchwork quilt"* in the dataset can be used as a predictor for the *patchwork quilt* principle from effectuation theory. Still, in practice users tend to use more than a few words (and less than a paragraph) to express what they are doing. For this reason, sentences were identified as an appropriate unit of analysis, allowing for richness of detail, while at the same time avoiding too much overlap between tags.

To track a given *theoretical concept* or *method*, the researcher first needs to derive the heuristic(s) related to the concepts. When these *heuristics* are in place, the computer needs to be trained to recognise the heuristic semantically (*supervised learning*). To do this, the computer needs a tagged training set. To this end, a "python script" (www.python.org) has been written to extract random sentences from the database. To extract sentences, the open source Natural Language Toolkit (www.nltk.org) has been used. The machine learning capabilities of the script have been created based on another open-source library called Scikit Learn (www.scikit-learn.org).

When each sentence comes up, the researcher evaluates whether one of the heuristics is represented in the text. If so, the researcher tags the sentence with this and any other relevant heuristic, by inputting a code unique to each tag (heuristic). This process of surveying and tagging random sentences from the data continues until a sufficient amount of sentences have been tagged – typically at least 2000 sentences. The ability of the *classifier* to precisely assign labels is done by saving part of the tagged data set as a *test set* (not used for training the classifier) and comparing the labels assigned by the researcher to this dataset with the labels assigned by the classifier. A good classifier will have a precision of over 80%. If it fails to meet this goal, more sentences need to be tagged and used in training the classifier.

As mentioned earlier, *unsupervised learning* can be used in a more exploratory way or as a first step, if no existing conceptual framework exists. If unsupervised learning methods are used, the untagged training data is fed into a clustering algorithm, such as a *DBSCAN* [Ester et al. 1996] or *k-means* [Arthur & Vassilvitskii 2007]. These algorithms find clusters by looking at the proximity of data entries – the exact principles of clustering are discussed in depth in chapter 6, study 3. The features of each cluster can then be inspected to see if they constitute a meaningful concept / topic. If a cluster is thought to be meaningful, the cluster can be used directly as a tag for new data.

The tagged training set can then be used for training a classifier to recognise tags. See a graphical representation of the training process in Figure 51.

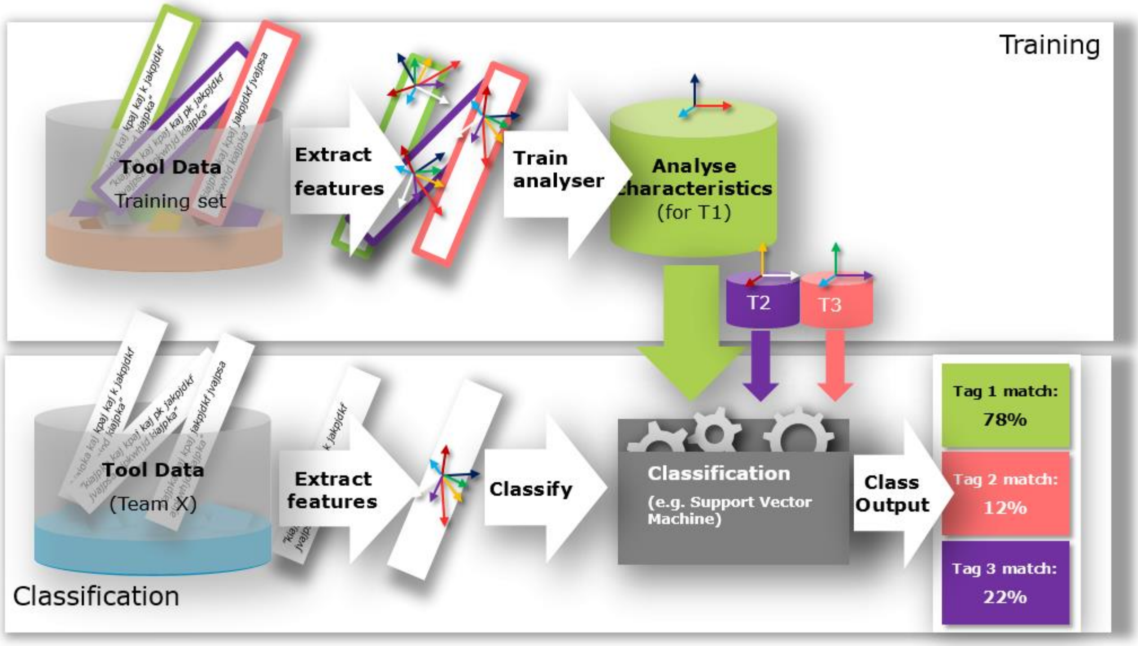


Figure 51: The process of training a classifier to recognise tags, starting with a tagged training set. [own]

After this, the classifier can be used to consistently classify sentences in perpetuity. It is, however, important to note that any coder errors made in tagging the training set will also be perpetuated indefinitely. To avoid issues with *interpretive validity*, it is therefore feasible to have separate coders code the same training data (as in e.g. [Stempfle & Badke-schaub 2002]). This potential caveat is however offset by the fact that as long as the machine learning method used is a simple type, peers can easily review the classifier and evaluate the validity of the features used in assigning each tag. This transparent nature of the process greatly strengthens the *interpretive validity.*

5.4.2.1 AUTOMATED PERFORMANCE MEASUREMENTS

The method for tracking heuristics outlined above can also be used for tracking various performance metrics. As an example, the initial survey done for the project teams gauges the maturity of the venture by asking a number of questions; one of these is "*Do you have any type of commitment from the first customer?*". The user can respond to this question by picking an option within an ordinal range:

1. *None*
2. *Customer contacted*
3. *Early dialogue*
4. *Expression of interest*
5. *Letter of intent signed*
6. *Order signed*
7. *First solutions sold to customer*
8. *Customer has purchased solutions several times (returning customer)*

These options on the ordinal range can be used in the same way as heuristics to train a computer (Figure 51). Quantitative measures can also be tracked in a similar way – by using ordinal ranges: E.g. "*Between USD 100-500.000 raised*", "*More than USD 500.000 raised"* etc. Although possible in principle, performance measures will not be included in the studies presented in the coming chapters of the thesis.

5.4.3 THE EMERGENCE OF A SEMI-AUTOMATED INTERPRETIVE METHODOLOGY

As is clear from the above sections, the areas of *natural language processing* and *machine learning* hold great promise for supporting research efforts based on large, qualitative datasets. The methods discussed also offer some unique opportunities with regard to accounting for the factors influencing research rigour – *validity*, *bias*, *generalisability* etc. Collectively, the data capture- and interpretive elements described above constitute a new Entrepreneurship Process Research (EPR) methodology, which will be summarised below.

Figure 52 shows the layers of the methodology; on top, the conceptual layers are shown (blue and green). This is the domain of theoretical and normative research. Heuristics constitute the most practice-oriented concepts, theories the least. Below the conceptual layers are the empirical layers. The process data layer is the database created by the EPR tool. The performance layer consists of performance measures, which are analytically derived from the process data (as described in the previous section).

One important feature of this model is that whenever an arrow line crosses a white space between layers, decisions and assumptions are made, which the researcher should be aware of and make explicit, in order to account for the rigour of the research. The biggest space is between the heuristics and the process data. This space is crossed using the *machine learning / natural language* based approach presented in the previous section.

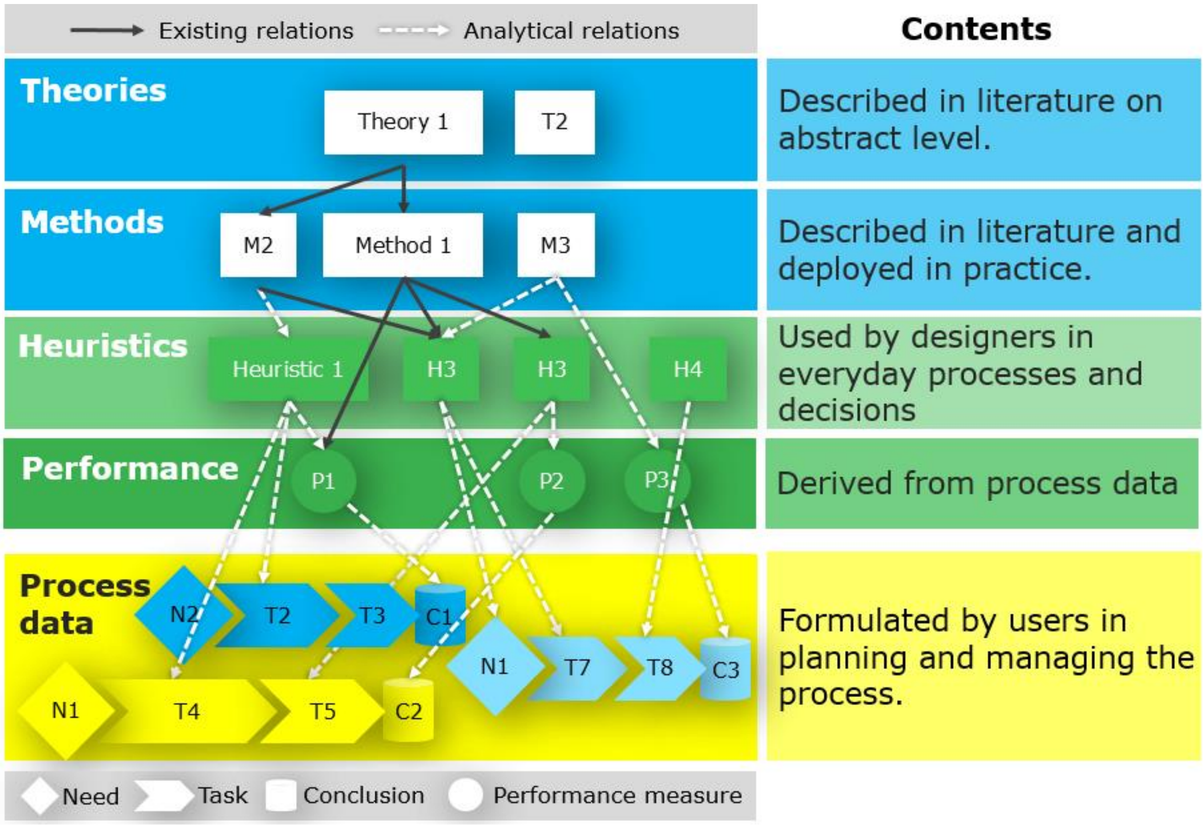


Figure 52: The layers of the research methodology (note that several elements from the database have been excluded for the sake of simplicity) [own]

The layers shown in Figure 52 create a basis for various types of studies – all using the process data gathered by the EPR tool as the empirical basis. In Figure 53, three archetypical studies are shown in relation to the layers of the methodology. These archetype studies are *deductive*, *abductive* [Robson 2011] and *optimisation.*

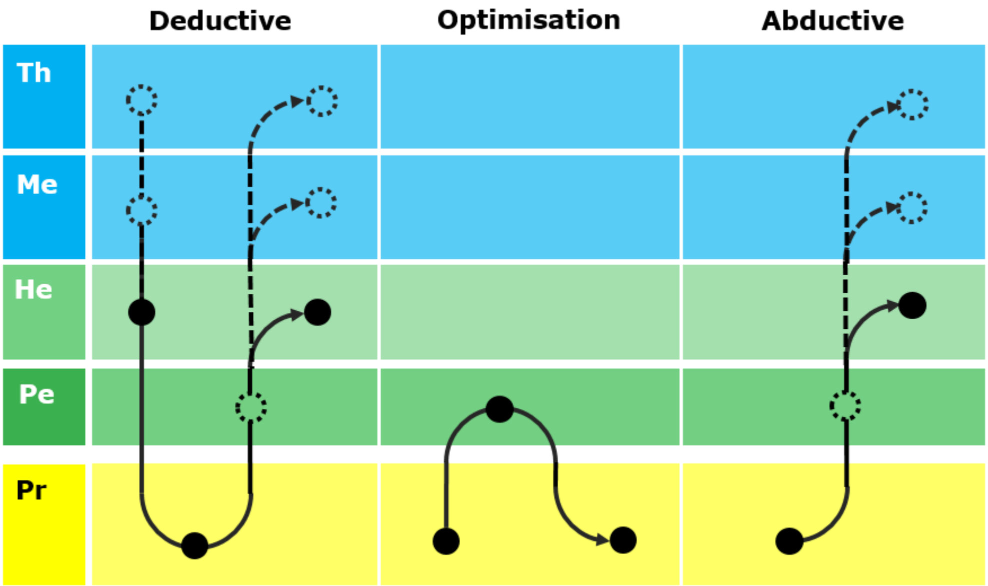


Figure 53: Archetypical studies using the proposed research methodology [own]

These can be used in extension of each other or separately, depending on the research goal. Below, each of the three study archetypes will be presented. These are to be seen as examples from a continuum of different studies, which can be conducted based on the new methodology. Practical examples of each archetype will be provided in the next section.

5.4.3.1 DEDUCTIVE STUDY

In a deductive study, the goal is to empirically test a theory, a method or certain heuristics. In other words, the study has a clear theoretical basis on which research questions are phrased and hypotheses made. This means that, unlike the *flexible research designs* [Robson 2011] presented and evaluated thus far, this type of study is what Robson calls a *mixed research design* as the methodology allows for structured as well as explorative elements.
Figure 54 shows the steps involved in conducting a *deductive study* using the new methodology.

Testing can mean proving the ability of the concept to describe the phenomenon (*theoretical validity)* and/or proving the presence of the outcomes predicted by the theory/method/heuristic. To achieve this, the methodology is used to first train a classifier (computer) to recognise the relevant heuristics and performance measures. As indicated in Figure 54, these heuristics and performance measures can be pre-defined, but in other cases, these have to be derived from a theoretical or methodical level.

When heuristics and performance measures have been defined, they are used for training the classifier. This is done by tagging sentences from a subset of the entire dataset - the *training set*. Also, a subset of the data is tagged and saved for testing the precision of the classifier. When the precision of the classifier is sufficient (>80%), the next step is to track the *performance measures* and *heuristics* in the data. If the dataset is very large, the researcher can choose to use the contextual dimensions provided by the *project survey* to filter the sample based on theoretical considerations (*dimensional- or quota sampling* [Robson 2011]).

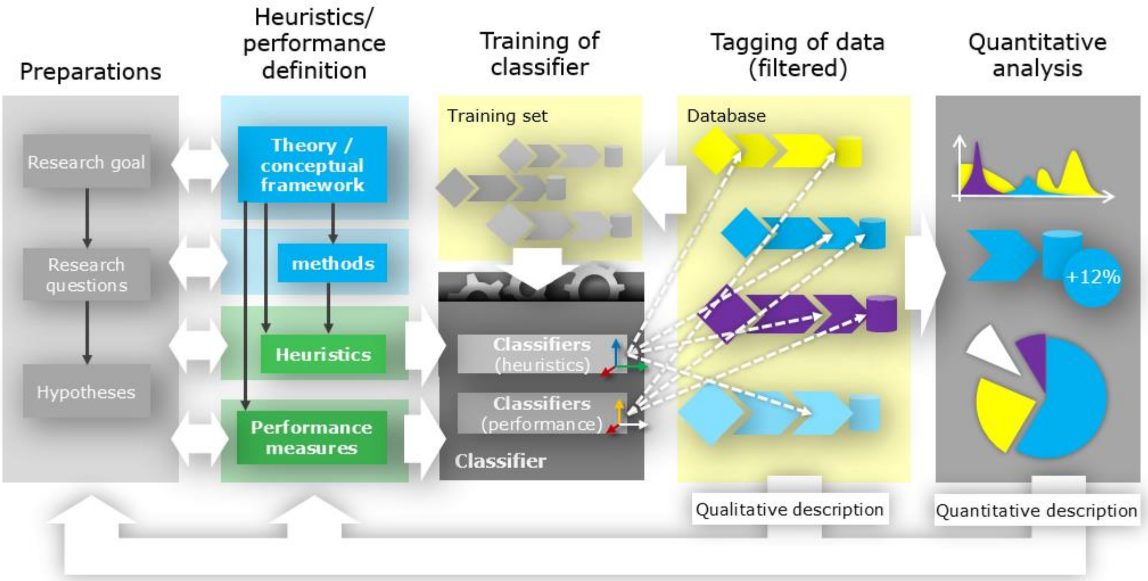


Figure 54: An example of the steps involved in conducting a deductive study [own]

With the sample in place, the EPR tool will scan the sentences in all parts of the dataset and assign tags to whichever elements (*needs, tasks, achievements, messages* etc.) match the features found for that tag during training.

In the current version, the script allows the researcher to visualise the tags (i.e. *heuristics* or *performance measures*) as additional nodes in the network representation, introduced in Figure 41 – see an example in Figure 55. A node representing the tag will appear at the bottom of the network and all the tagged elements (nodes) will be linked to this node by an edge (line connecting two nodes). This representation enables the researcher to qualitatively investigate the network and see where and in which context the heuristics and performance measures are represented. This forms a good basis for establishing causal links between elements of the process, the heuristics and the performance measures.

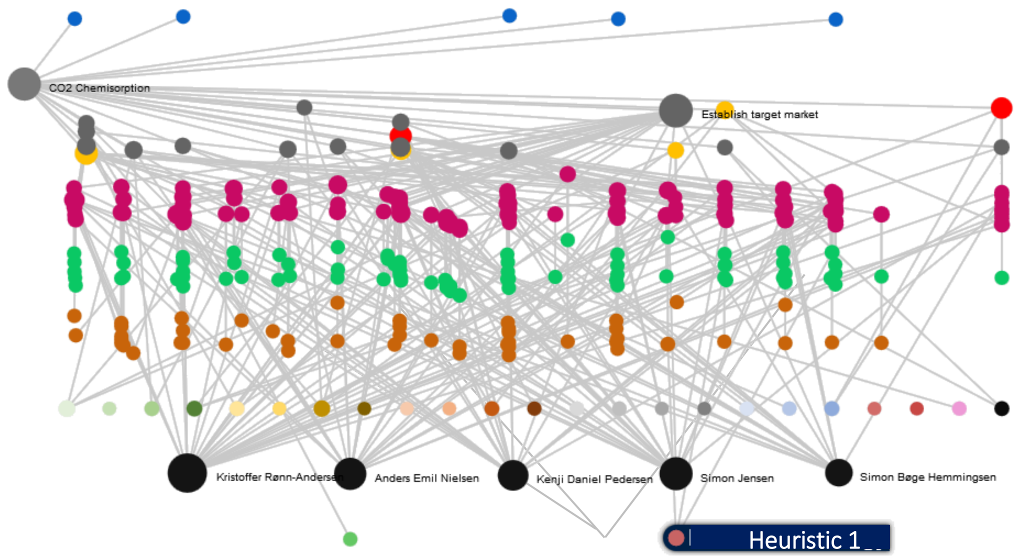


Figure 55: Mapping of heuristics in network representation (heuristic node highlighted) [own]

From here, the researcher can also proceed to various quantitative analyses of the tagged data: E.g. the prevalence of certain heuristics over time, the development in performance measurements, composition of various heuristics etc.

These qualitative and quantitative descriptions of the phenomenon can now be used as a basis for testing the components and predictions of the theory, the method or heuristic.

5.4.3.2 ABDUCTIVE STUDY

Another study type is the *abductive study*, where no prior conceptual framework exists for the phenomenon. Instead of finding heuristics and performance measures to use for *supervised machine learning*, this study type employs clustering techniques that are *unsupervised*. Figure 56 shows the steps involved in conducting an *abductive study*.

The clustering algorithm (e.g. DSCAN or *k-means*), takes the text data from the entirety of the dataset in the form of sentences. These sentences are then turned into N-dimensional (N is the total number of words used in the dataset) vectors, which can be compared. A distance between sentences is then calculated based on the vector. This distance is used for grouping sentences of similar characteristics in clusters.

The resulting clusters can then be inspected by the researcher to see if there is any meaningful consistency in the terms and semantics listed as features for each cluster. Often, the clusters will be seemingly random and offer little insight. Also, significant overlap between clusters is normal. However, in certain cases, clusters can be identified, which have a coherent and meaningful set of features. This process is very akin to what *grounded theory* researchers would experience in building concepts based on qualitative data [Charmaz 2006; Glaser & Strauss 1967]. Unlike *grounded theory*, however, the emerging clusters can now be used to automatically tag current and future data.

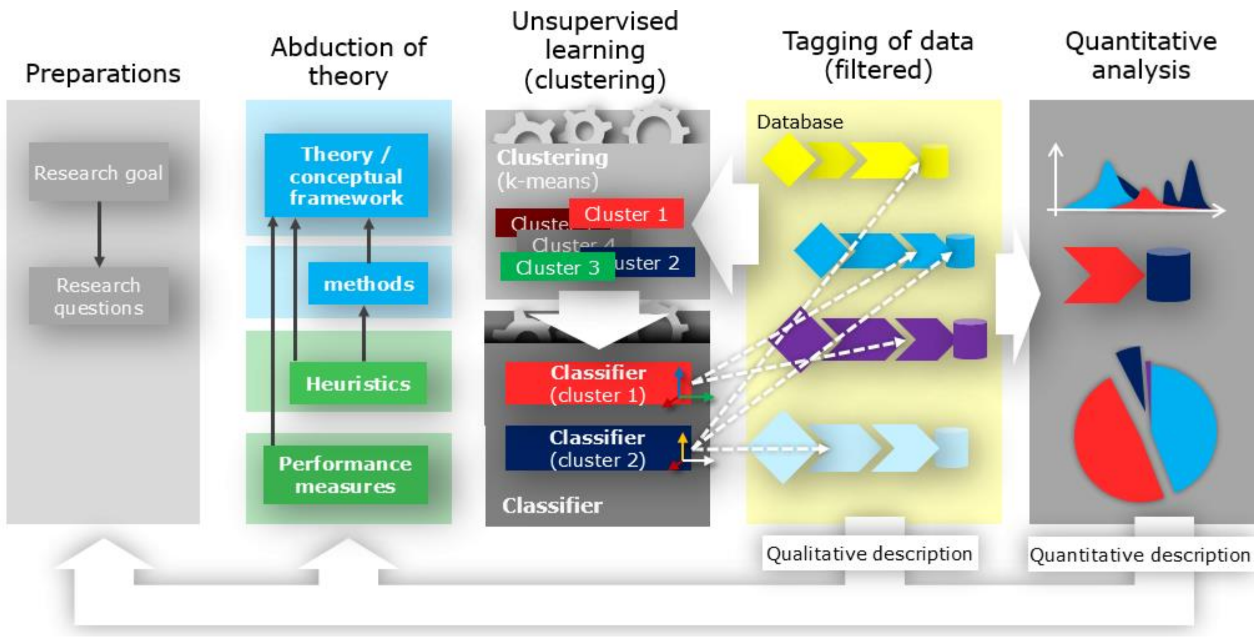


Figure 56: An example of the steps involved in conducting an abductive study [own]

As with the deductive study, the tags will appear as nodes in the network representation, enabling the researcher to qualitatively evaluate the cluster's role in the process and its relation to specific elements. Similarly, the study can proceed to a quantitative analysis of the cluster, its development over time, composition, relation to other variables, etc.
As an added option, the correlation between cluster prevalence and various performance metrics can be investigated, to determine if the clusters influence the process in a positive or negative manner.

The qualitative and quantitative analyses of the results can be used as a basis for identifying new *performance measures* and *heuristics*. These, in turn, can be used for the abduction of new *methods* and *theories*.

5.4.3.3 OPTIMISATION (STUDY)

The last study type is in fact not really a study, as it has no theoretical objectives. It is included because it serves as a shortcut for achieving some of the objectives of entrepreneurship process research – i.e. improving the way in which entrepreneurs build their business. This can be done through the application of *theory*, *methods* and *heuristics*, but it can also be done by sharing process information.

In Figure 57 the *optimisation study* is shown. This model presupposes that one classifier has been trained to track various process measures of interest to the entrepreneur. Also, it presupposes that the *needs* in the database have been clustered based on similarity. If this is in place, a user expressing a new need (shown as light blue diamond), can query the EPR tool for suggested solutions.

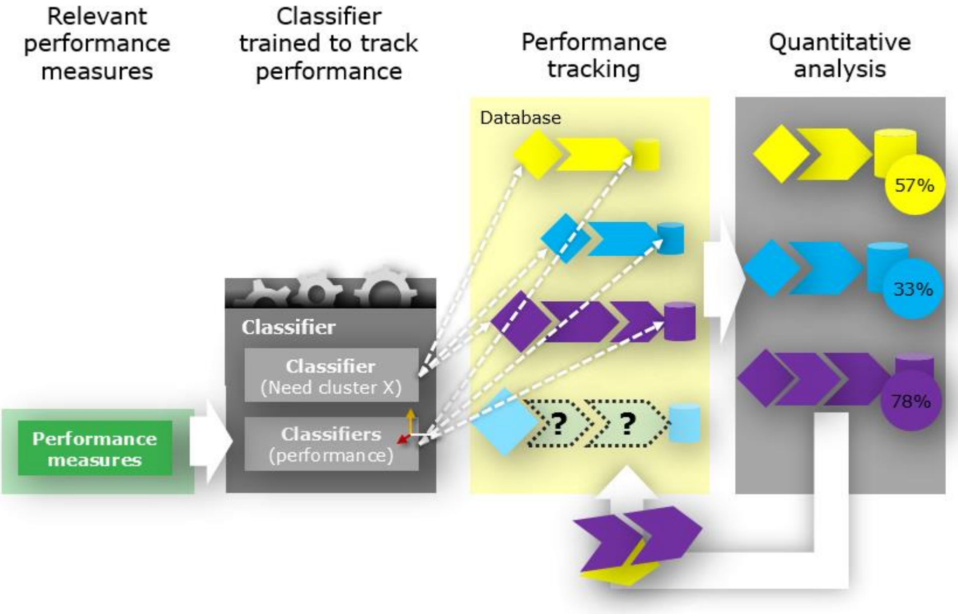


Figure 57: Process optimisation using classifiers. [own]

To provide these solutions, first needs of similar type are identified in the existing database, using the need cluster classifier just mentioned. This should yield a list of *needs* with associated *tasks* and *conclusions*. Then, using the performance measure classifier, the performance of each concluded need can be determined and the various approaches for solving the need can be ranked from best to worst performing. The top approaches on the list can then be conveyed to the user looking for a solution. The proposed solution is in the *need/task/conclusion* formulation of the user, who originally filled in the data. It is up to the current user to make sense of whatever the previous user filled in.

In the short term, it is not a given that this method for supporting the user will be able to produce easy to understand, relevant recommendations. However, as the amount of data in the database grows, the more solutions will be available and the more relevant the match. The method does however provide a novel way of querying process knowledge.

5.5 EVALUATION OF THE EPR TOOL AS AN ENTREPRENEURSHIP PROCESS RESEARCH

Together, the data-analysis features presented above and the EPR tool form the basis for a new Entrepreneurship Process Research (EPR) methodology. In any case, the tool should be evaluated in terms of the requirement specification formulated in the previous chapter. In Table 14, the requirements will be treated separately.

From the table it is clear that the EPR tool generally fares well in terms of the stated requirements. Some issues do however persist, of which users of the tool should be aware.

In its current form, the EPR tool does not capture short-duration events particularly well. To address this, it is suggested that in certain strategic times, the tool is used in conjunction with other research methods, such as participant observation (perhaps combined with video- or sound recordings), to ensure the capture of *micro strategies* [Gero & McNeill 1998]. Such strategic times could be the first meeting with a customer, initial test of a prototype, and so forth. The EPR tool can be used to identify the emergence of such occasions.

Also, the use of other research methods would enable *methodological triangulation* of the captured data. This could be particularly useful in the initial stages, to help establish confidence in the EPR tool as an appropriate method for data capture.

Requirement derived from entrepreneurship process theory			Notes on compliance
Individual	**1.1**	*Capture the individual's traits and cognitive propensities.*	Done using the team member survey, but the actions (defined tasks, messages etc.) of the team member also reveal insights.
	1.2	*Capture changes over time in the former.*	The description provided in the tasks and messages reveals how cognitive strategies evolve over time.
Environment	**2.1**	*Capture data on environmental characteristics.*	The environmental characteristics are an inextricable part of the needs, task and achievement descriptions. Also, they are registered in the *project survey*.
	2.2	*Capture changes over time in the former.*	The qualitative descriptions of the subjects will reveal the temporal developments.
Organisation	**3.1**	*Capture data on organisational characteristics.*	The organisational characteristics are covered in the *project survey*, but also in the ongoing data captured in the needs, tasks and achievements. Need categories relating to the organisation are also hard coded into the EPR tool.
	3.2	*Capture changes over time in the former.*	The qualitative descriptions of the subjects will reveal the temporal developments.
Opportunity	**4.1**	*Track and document the opportunity.*	The opportunity is typically covered in reports on *achievements* and in the *conclusions*.
	4.2	*Capture relations between opportunity and solutions.*	The link between opportunity on one side and the solution on the other is often provided in the form of a *need* and its corresponding *tasks/conclusions* respectively. Need categories such as *value propositions* can be used to identify elements dealing with this topic.
	4.3	*Capture changes in opportunity understanding over time.*	Again, the qualitative descriptions provided over time can be used as a basis for following changes.
Cognitive strategies	**5.1**	*Capture data on the cognitive strategies of the entrepreneur.*	The description of tasks and the problem solving discussions in the conversation module can provide valuable insights into the cognitive strategies of team members.
Entrepre-neurship process	**6.1**	*Describe process in terms of transformation of inputs into outputs.*	The underlying conceptual framework is defined in terms of inputs (needs), transformations (tasks) and outputs (conclusions/resources).
	6.2	*Document the changes to individual and social dimensions.*	These changes should be discernible from the qualitative descriptions made by the users. *Private life* and *team* are included as need categories dealing with social dimensions.
	6.3	*Capture process dynamics data.*	The conceptual framework is based on a process dynamics perspective.
	6.4	*Capture activity durations down to <10 seconds (no upper limit).*	The main weak point of the EPR tool in terms of the requirements. The conversation module has shown that very short-term data can be captured, but it has not been widely adopted.
	6.5	*Capture context for activities.*	The network structure of the data and the *project survey* ensures that all pieces of data are described in relation to their context. The extensive need category system enables quick identification of a particular context.
Following the entrepreneur and avoiding obstruction	**7.1**	*Capture data at unpredictable locations and times.*	Being a software that runs on most platforms, the EPR tool can be used whenever the entrepreneur wishes.
	7.2	*Unobtrusive to the process observed.*	The EPR tool is designed to increase transparency and help the entrepreneur. As discussed, it affects the process, but not in an obtrusive way.
	7.3	*Create value for entrepreneur.*	The EPR tool is designed to help the entrepreneur gain an overview and manage the process. Users have reported that the tool succeeds in doing so.

Requirements derived from technology development research

Technological risk	**8.1**	*Determine if given venture is dependent on technology or not.*	Questions positioning a given project in terms of technology dependency have been included in the project survey.
	8.2	*Determine technological risk*	The questions posed (mentioned above) can be used to gauge the technological risk. However, a more direct set of measures will be implemented in future versions of the EPR tool.
Influence of tech	**9.3**	*Capture relations between technology and conceptual components.*	The need categories related to technology/development/R&D and prototyping make it straightforward to identify elements dealing with technology. The qualitative descriptions provide a deeper understanding.

Requirements derived from qualitative research methodology

Descriptive validity	**10.1**	*Ensure consistent accurate and detailed data capture.*	The conceptual framework underlying the EPR tool ensures consistent data capture. The qualitative descriptions provided by the team ensures the necessary detail.
	10.2	*Capture data relevant and sufficient for supporting theory.*	If the theory can be converted into meaningful heuristics and performance measures, the data should be able to support the theory. As the dataset grows, so will the degree to which the data can support a given theory.
Interpretative validity	**11.1**	*Enable efficient and consistent interpretation of data gathered*	Using the methodology described above enables the researcher to interpret data in a transparent and extensible manner.
	11.2	*Enable clear communication of interpretative steps.*	The tagging of training data, the use of classifiers and/or the application of clustering algorithms are all interpretive steps, which can be clearly explained.
Theoretical validity	**12.1**	*Explicitly state the theoretical underpinnings of the study.*	The conceptual framework and its potential weaknesses have been discussed in detail.
	12.2	*Make disagreements on theoretical perspectives explicit.*	The conceptual framework constitutes common grounds for a field, which is faced with many diverging theoretical perspectives.
Generali-sability	**13.1**	*Describe sample in terms of the theoretical basis for the study.*	The *project survey* and *team member survey* provide the necessary data for understanding a given project in terms of widely adopted theoretical frameworks (e.g. [Gartner 1985])
	13.2	*Enable evaluation of internal and external generalisation.*	The extensive contextual data gathered for each project provides a basis for evaluating the external generalisability of the data. If provided by different users, the achievements and messages create a basis for evaluating internal generalisability.
Bias	**14.1**	*Account for potential bias issues in research method.*	The conceptual framework imposed on the process will create reactive effects, but these effects will be isolated to certain parts of the phenomenon, which have been discussed.
Triangulation	**15.1**	*Use triangulation to strengthen rigour*	The EPR tool uses data triangulation in that the information covered in the need and task descriptions is (conceivably) covered in a different format in the achievements and conversation module.

Table 14: The EPR tool's compliance with requirements.

5.6 CONCLUSION: A NEW PROMISING TOOL FOR ENTREPRENEURSHIP PROCESS RESEARCH

This chapter has described the development of the EPR tool based on the requirements set forth by the phenomenon and considerations on research rigour. In the process of developing the tool, a number of new ways of visualising data have been conceptualised along with a novel way of analysing the qualitative data. As such, the EPR tool is part of a research methodology (the EPR methodology) centred on the tool as a data capture method. The potential uses of the methodology were also described in the form of three archetypical study designs.

Finally, the EPR tool and the EPR methodology were evaluated against the stated requirements. This evaluation showed good compliance with the requirements, but also a need for supporting the with other research methods such as *participant observation*.

At this point, the thesis has dived deeply into academic and methodological dimensions. This constitutes a departure from the initial, practical objective of the thesis: To support Danish maritime suppliers in entrepreneurial efforts building on technological knowledge. With the EPR tool now in place, the thesis can begin to move back towards the initial objective. As established in chapter 3, the major hurdle for creating relevant support for technology entrepreneurship processes is the lack of empirical insights. In the coming chapter, the EPR tool and -methodology will be used to create a number of valuable, empirical insights.

5.7 REFLECTION ON CHAPTER CONCLUSIONS

In the evaluation of the EPR tool, it is found to comply well with the requirement specification formulated in chapter 4. However, the tool has thus far mainly been tested on academic entrepreneurship cases: *Is the EPR tool also appropriate for supporting and researching venture processes at Danish maritime suppliers?*

In chapter 2, section 2.6 (page 24), the similarities between *entrepreneurship* and *radical innovation* were discussed. It was shown that for radical innovation to succeed (in innovation hubs), the organisation should maintain a low profile and start with a small team [O'Hare et al. 2008] and that the organisation should be flexible and willing to experiment [O Reilly & Tushman 2004]. At the same time, it is useful for the main organisation to have a clear understanding and realistic expectations for the activities of the spinout / innovation hub [O'Hare et al. 2008].

The EPR tool's ability to support small project teams in information sharing and agile task allocation and its features for allowing external stakeholders (e.g. management) to follow and understand the process, means that it is well aligned with the needs described above. Having said this, the EPR tool has now reached a maturity level, where the next obvious step is to apply it to actual technology spinout projects in a maritime supplier company. This is, however, beyond the scope of the present thesis.

On a more research methodological level, the issue of *reactive effects* has been highlighted several times in this chapter. It is believed that the current formulation of the tool strikes an acceptable balance between providing value for the entrepreneurs without interfering excessively with the phenomenon being studied. However, in the eyes of the entrepreneur, the tool is a software platform like any other and like all other software platforms, the users' needs for functionality and features is to be accommodated if they are to continue using the tool. In this regard, the tool is in direct competition with other project tools, which do not share the second role of also being a (rigorous) research tool. Also, from a research point of view, it would also be preferable if the format of the tool's data were kept in its current form for perpetuity, as this would enable direct comparison of all parts of the dataset.

The challenges listed are a result of the choice to embed a research tool in a software tool. As the following chapters will show, this strategy yields a number of opportunities, which outweigh the need for added attention to research rigour in the further development of the tool.

CHAPTER 6:
EMPIRICALLY TESTING AND BUILDING PROCESS THEORY

RQ2.3:
How can entrepreneurship research be strengthened to better cater to the needs of technology venture processes?

RQ3.1:
How can PSS and other design and innovation areas be used for supporting venture- and technology development processes?

With the Entrepreneurship Process Research (EPR) methodology in place, the road is paved for addressing the issue, which originally necessitated the development of the new research tool: The lack of empirical data on technology entrepreneurship processes and the resulting poor quality of theoretical models.

Over the chapter's three studies, an empirical basis for understanding the technology entrepreneurship process phenomenon is created and existing theories are tested against the substantial process dataset.

The first study seeks to explore and understand the contents of the large dataset created by the EPR tool. This study takes its point of departure in the existing structure of the tool (categories, surveys) and uses this to identify distinct characteristics for the different types of projects in the dataset.

The second study seeks to test Sarasvathy's theory of Effectuation on the data in order to verify that the theoretical components can be tracked using the EPR methodology.

In the final study of the chapter, a new conceptual framework is developed for describing the phenomenon and for providing a basis for determining the relevance of tools from PSS and design and innovation research.

As the EPR methodology is used for the first time in these studies, discussions on its use and validity will be provided throughout.

6.1 CHAPTER RESEARCH DESIGN

This chapter builds on the EPR methodology, which was introduced in the last chapter. Study 2 and 3 each use the methodology in one of the archetypical ways described in the previous chapters. To conduct the studies, a number of traditional methods were also used. The specific discussions on research rigour (*validity issues, bias*, etc.) will be treated in the study description itself. The following sections summarise the adopted methodological approaches and provides some notes on methodological considerations.

6.1.1 STUDY 1: TESTING HEURISTICS ON PROCESS DATA

Together, the surveys available for each project and the structured (see chapter 5, page 82) data from the tool form a platform for studying the processes of the entrepreneurial teams. In this study, the contents of the current data sample are discussed, in terms of bias and validity issues. After this, diverging parts of the sample are compared, to establish an understanding of the probable relations (as opposed to causal relations) between various contextual parameters and the behaviour of the team.

6.1.2 STUDY 2: TESTING HEURISTICS ON PROCESS DATA

In this study, the process data captured using the 2nd prototype of the tool (11 projects in total) is used for tracking the use of *effectual* principles [Sarasvathy 2008]. This is achieved using the *deductive study design* of the EPR Methodology. The *effectuation* principles are used directly as *heuristics* for tagging a training set from the tool's database. A *predictive strategy* tag is added, as such a heuristic is explicitly stated by Sarasvathy as a contrasting cognitive strategy, also used by entrepreneurs.

Approximately 3500 sentences are tagged as a basis for training the machine learning algorithm. Due to a lack of semantic examples of certain *effectual* principles, a decision is made to combine the *effectuation principles* into one tag called *effectual strategies.*
To triangulate the data, a supervisor, who has closely followed all the projects in the study, is asked to rate the extent to which each team had employed *effectual*- and *predictive strategies.*

6.1.3 STUDY 3: BUILDING THEORY FROM PROCESS DATA

In this study, the inductive study archetype was used as a template. Instead of relying on existing *heuristics, performance measures* or a *conceptual framework*, this *flexible design* study was designed to show the *explorative* capabilities of the EPR methodology.

The study is entirely based on the qualitative data in the dataset and the analysis of this data is done by way of a variety of *grounded theory* supported by advanced *natural language processing* and *machine learning* algorithms.

The explanatory power of the resulting *conceptual framework* is validated by applying it to a known case of technology entrepreneurship in the maritime branch.

6.2 STUDY 1: A GLOBAL VIEW ON ENTREPRENEURSHIP PROCESSES

Based on the EPR Methodology various studies can be designed, which enable the researcher to answer specific research questions. Furthermore, the tool also provides a large amount of structured data, which can be used as basis for understanding the entrepreneurial process.

The network representation of the tool data has already been mentioned in section 5.3.3.1 (page99) – it constitutes a visual approach to qualitative analysis of the large amount of data produced for each project. Despite being an efficient way for representing a large amount of data, the network representation is an inappropriate method for gaining insights across projects.

On page 108, Figure 48 shows a ranking of the 50 most active projects in the tool database. It features counts of three database classes, which account for the majority of the data for most projects – *need revisions, task revisions* and *resource revisions.*

In total, the database contains 199 projects at the time of writing. With the drop-off seen in Figure 48, it is clear that not all of these projects are likely to provide detailed and meaningful inputs. Of the teams shown in the top 50, 34 are directly related to the course on technology entrepreneurship mentioned several times in the description of the tool's development. In other words, any analysis of data across the projects of the database will be heavily affected by the large amounts of data coming from the course projects.

The discussions in this section are therefore to be seen as particularly representative for this group of tech entrepreneurship. However, as most of the very active projects have filled in the project survey, a platform exists for *theoretical sampling* [Robson 2011], where the sample can be described in terms of the underlying theoretical framework for the phenomenon. If the samples validate the theoretical predictions for phenomena with these characteristics, this is a good indication of *theoretical validity* and the researcher can be more confident in using the empirical results in *external generalisations* to other samples characterised using the same framework. However, in this study, the purpose is merely *explorative* and no theoretical/conceptual framework is imposed.

6.2.1 UNDERSTANDING THE SAMPLE

Features of interest in the contextual data gathered for 63 out of the 199 projects are now treated in turn. In total, the survey contains 29 questions about the projects, their *market*, *the idea, the team, the technology* etc. The response features discussed below represent a subset of these questions.

6.2.1.1 MARKET AND IDEA NOVELTY

The survey shows that the ventures using the tool operate in markets of varying maturity. Figure 58 shows that 46% of the projects respond that the *market is established and stable* or *established but changing slightly.* This is an interesting feature in terms of a *Shanian* perspective on entrepreneurship [Shane & Venkataraman 2000] which separates the novelty of the *opportunity* from the novelty of the *means-end* relationships used for exploiting the opportunity. In this perspective, the effort to exploit an existing opportunity using new *means-end* relationships is still considered as being entrepreneurship. Although not a direct indicator for new *means-end relationships*, the second graph in Figure 58 indicates that the ventures in the sample are predominantly (81%) dealing with solutions that offer moderate to large improvements or that currently have no comparable solution in the market.

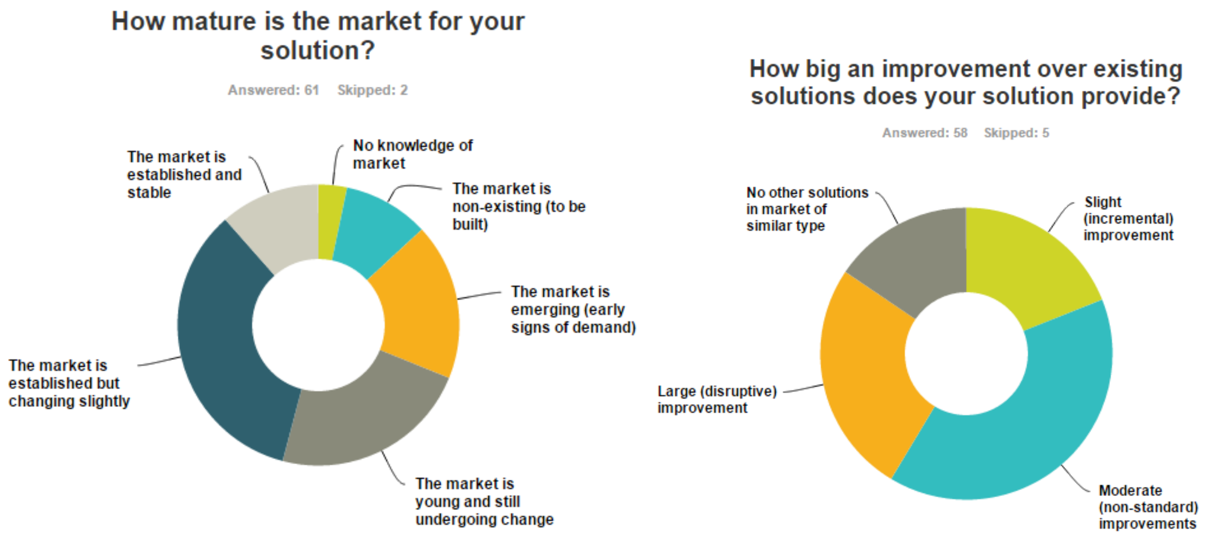


Figure 58: Market maturity (left) and disruptiveness of idea (right) from survey responses. [own]

6.2.1.2 CUSTOMER RELATION

As an added note to the *means-end* points just made, it seems that the ventures in the sample are generally departing from a *means-end* starting point, as 55% of the respondents state that they either have a vague knowledge of their first customer or no knowledge at all (see Figure 59). This is indicative of the ventures being founded on a technological insight rather than a concrete market opportunity – this is clearly coupled to the fact that so many of the ventures are related to a course on technology-driven entrepreneurship.

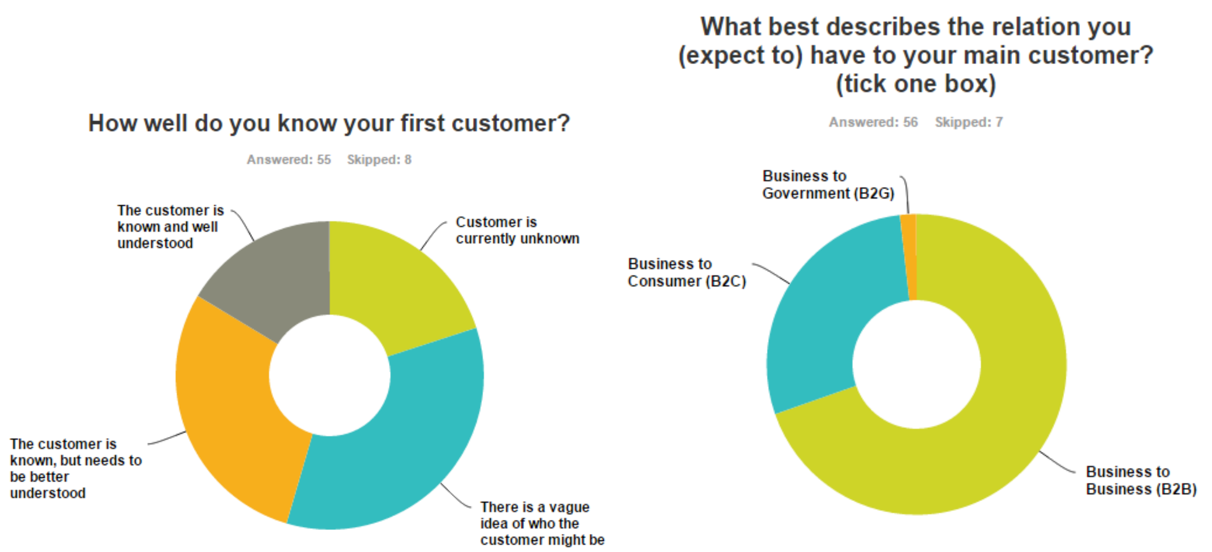


Figure 59: Knowledge of the first customer (left) and the type of relation (right) [own]

Another interesting feature of the responses from the sample is the type of *organisations* found in the sample. According to Gartner [Gartner 1985], the organisation for each venture needs to be characterised, in order to understand differences in entrepreneurial processes. In the present sample 70% of the ventures report that they are working with solutions in the business-to-business (B2B) space – as opposed to the business to consumer space (B2C). The survey also provides qualitative feedback in the form of sector names. Here, a wide variety of sectors is mentioned, including several instances of *maritime* and *med tech* ventures. The sectors reported also include, *renewable energy* and *industrial automation.*

6.2.1.3 STATUS OF VENTURE

The project survey also features questions on the status of the venture. The purpose of these questions is to determine the development stage of the venture. 57% of the ventures in the sample are either hobby projects or projects being developed without a company having been formed. The differences in processes seen between the legally formed companies and these unregistered ventures are potentially interesting in terms of Carter's *quantification sequence* (see Table 3, page 39), which includes the stages *starting up, still trying* and *given up* [Carter et al. 1996]. Carter has identified significant differences in behaviour and work intensity between legally incorporated companies and unregistered ventures.

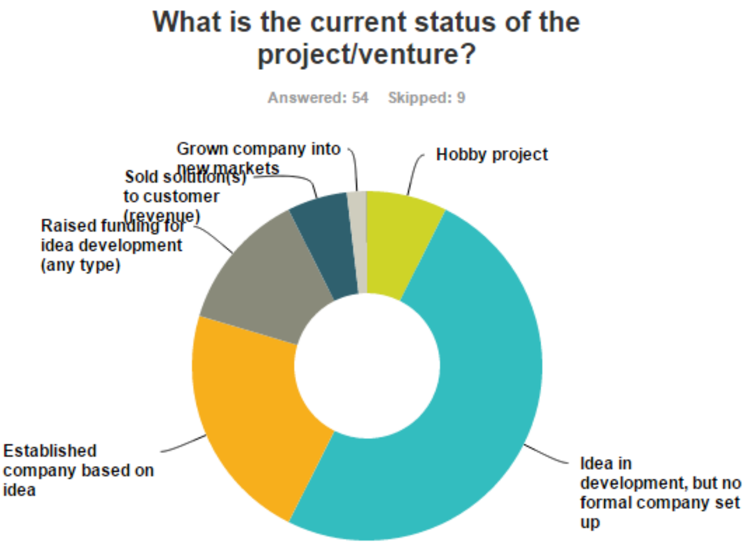


Figure 60: Status of projects [own]

6.2.1.4 TECHNOLOGY

The technology risk matrix [J. Mankins 1995; Louis Anthony Tony Cox 2008] was introduced in chapter 3. Three central components are used to evaluate technological risk – the maturity- (*TRL*) the importance/value (*TNV*) and the difficulty in development (*R&D3*) of technology. The project survey features questions that indirectly can be mapped to these components: The question regarding the technology's importance to building a competitive business (Figure 61, top graph) is closely related to the TNV and the readiness question (middle graph) is closely related to the TRL. The *R&D3* component is partly related to the question concerning the expected share of the total budget used on technology development (bottom graph, Figure 61).

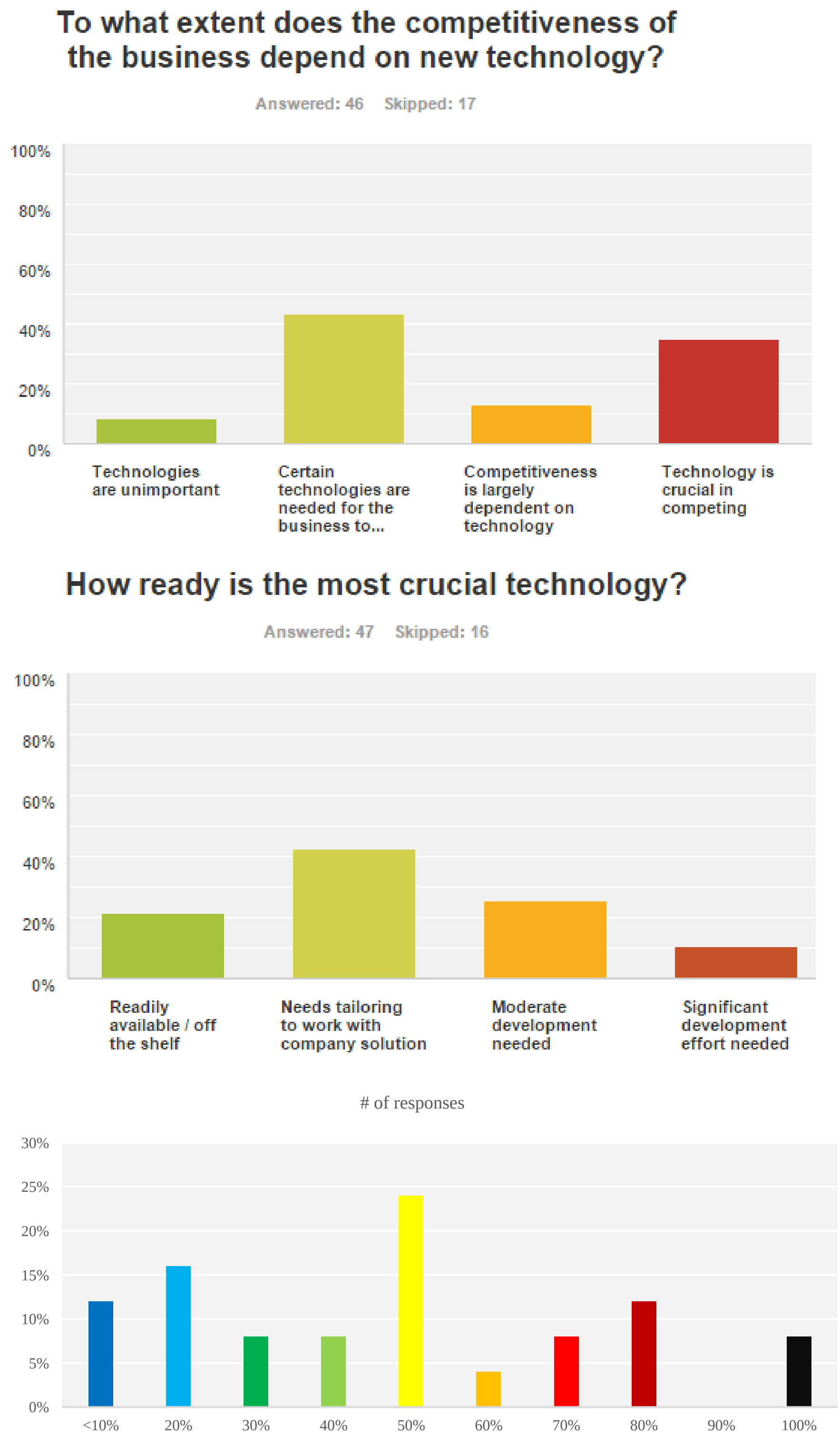


Figure 61: Components of technological risk – importance (upper left), maturity (upper right) and technology development's expected share of total budget (bottom). [own]

From this data, it is clear that technology plays a role in most of the ventures in the sample with only 8% reporting that technology is unimportant. The technological risk is however mitigated by the fact that, although important, the technologies are relatively mature – only 11% report that significant development efforts are needed. The degree of difficulty in the form of expected spending in R&D seems to vary quite significantly within the sample. Some ventures (8%) report that they expect to use 100% of the budget on technology development.

This extreme number indicates that the team member who has responded to the survey has a very monolithic (technology-centric) view of development and that the response should therefore not be seen as a dependable proxy for gauging R&D3.

6.2.1.5 THE USE OF STUDENT PROJECTS

As already mentioned, a large share (~88%) of the data points in the database come from projects, which were part of a project-based course on technology entrepreneurship. As these projects will invariably bias the data gathered, a discussion on whether this bias is a problem is needed. The concern for biasing issues arises due to the fact that the use of students instead of "actual" practitioners will yield different results, which often are not representative of the "real" phenomenon (see e.g. [Cash 2012]). The entrepreneurship processes in Danish maritime ventures - a special case within the "real" phenomenon – are of particular importance to this thesis and will be given special attention.

In short, *is there a reason to consider student driven, course-based entrepreneurship processes as unrepresentative of "real" entrepreneurship processes?*

To answer this question, one first needs to bear in mind the very diffuse definitions of who the *entrepreneur* is. In Shane's definition, the *entrepreneur* is someone able to identify *opportunities* and leverage new *means-end relationships* in exploiting these. Bruyat & Julienne talk about entrepreneurs as someone who has committed to engaging in the *I⇔NVC* dialogue [Bruyat & Julien 2001], meaning, that the entrepreneur has to actually work to pursue the opportunity – not just think about doing so. None of these definitions exclude what happens in course project as long as the participants are actively working to exploit new *means-end relationships.*

It is difficult to compare the student projects with entrepreneurial projects in the Danish maritime supplier companies, as the whole notion of entrepreneurial strategies is new to the Danish maritime branch. There is simply no known basis for comparison. Studies on radical innovation in other industries can however be used to form a rough basis for comparison. In the reflection on chapter 5 (section 5.7, page 121) and in the original discussion about entrepreneurship in maritime supplier companies (chapter 2, section 2.6, page 24), it was shown that established companies can organise entrepreneurial projects in a number of ways – ranging from *corporate R&D* over *innovation hubs* to *spinouts* [O'Hare et al. 2008]. Furthermore, it was shown that for such ventures to be successful, the initial organisation has to be small and agile and that a certain measure of independence is needed. Entrepreneurial expertise is required, but the projects also need to maintain a coupling to the expertise and competencies of the organisation. These findings do not tell us anything about the existing nature of ventures in the maritime suppliers, but it does indicate how such efforts should be organised. The student projects in the dataset are characterised by small teams (4-6 persons) of varying entrepreneurial experience. The student teams are directly supported by the researchers behind the technology to ensure that the necessary knowledge and competencies are in place for developing the technology. In this way, the student teams exhibit several of the characteristics, which contribute to success. However, one could argue that the technology and market knowledge is not inherent in the team as opposed to ventures in a maritime supplier company, which will most likely be based on existing employees with experience in the field.

Another way of comparing "real" entrepreneurship projects (and the maritime special case) against the course-based projects is to look at the share of projects continuing after the course finishes. Despite being a difficult metric to assess, an estimated one in three projects have proceeded towards commercialisation after finishing the course. Out of the 60+ projects that have been part of the course, at least twelve companies have been formally registered at the time of writing. Although these numbers are difficult to compare to the “real” entrepreneurship projects and maritime ventures, it certainly attests the fact that the course projects are serious ventures.

Entrepreneurial experience is also an area that can be discussed. Students are unlikely to have significant experience with starting companies. Still, the team member survey has shown that several students have experience from one or more previous ventures. This reflects the fact that entrepreneurship is increasingly popular among students, who often run startups alongside their studies. In any case, experience in entrepreneurship is not a requirement for an entrepreneurial project. In fact, “real” projects and maritime ventures are also likely to exhibit the same variation in experience.

In the very early stages, entrepreneurs most likely work in their spare time and during work hours at their day job. Even if the entrepreneurs in the venture are paid by their company to pursue entrepreneurial opportunities (e.g. in a maritime venture), it will often still be a part time activity. This is not very different from the reality of the students, who can only work on the entrepreneurship project in the hours allocated to the course and in their spare time.

The next point to discuss is that of motivation. Students get course credits finishing the course and this can be seen as the main motivation for executing the process. Notwithstanding the points made above on continuation of projects after the course ends, this change in motivation does not necessarily differ from the “real” entrepreneurs who often work on their venture alongside their day job and in some cases - e.g. in maritime supplier ventures - the entrepreneur is paid to pursue entrepreneurial ventures as part of his/her day job.

The last point to be discussed is that of formal setting. Students working in a course have desks, internet, coffee and - in the case of the course mentioned – even limited financial support. Furthermore, the teams get training in entrepreneurship as part of the course. This again differs from many instances of “real” entrepreneurship. However, again it should be pointed out that a large share of “real” ventures are developed inside existing companies or in the increasingly popular and prolific “accelerators” or “incubators”, which typically offer office space, training, advise and financial support.

This discussion might seem like a case of cherry picking niche examples of “real” entrepreneurship to argue compliance with the student case. The point being made, however, is that entrepreneurship is a complex and diverse field. Rather than a discussion on whether the student projects are actual entrepreneurship, one should acknowledge that they are indeed a form of entrepreneurship and instead make sure that the relevant boundary conditions for determining the form are captured when studying the projects. This is the purpose of the *project-* and *team member survey*.

Evaluation criteria	*Student projects*	*“Real” projects in general*	*Maritime ventures*
Comply with definition of entrepreneur?(see above)	Yes	Yes	Yes
Share of projects becoming actual ventures (registered)	~1/3 continuation rate (after course). ~1/5 registering as companies.	N/A	N/A
Time use and dynamics	In between work in other courses, in spare time and in the hours allocated to the entrepreneurship course.	In between day to tasks and in spare time (early stage entrepreneurship).	In between other tasks, but possibly as full time occupation if resources are available.
Experience	Varied	Varied	Varied (team probably consists of existing employees).
Motivation and risk taking	Course credits. Potential upside of venture is successful. No risk exposure.	Wage from “day job”. Potential upside of venture is successful. Some risk exposure.	Wage for developing venture. Potential upside of venture is successful. No risk exposure.
Formal setting and resources	Course setting at the university Training in relevant methods Supervision / advise Financial support	Incubator or accelerator Training in relevant methods Supervision / advise Financial support	Ordinary workplace. Training perhaps provided by company. Advice from management (not entrepreneurship specific). Financial support.

Table 15: Comparing student entrepreneurship projects with “real” entrepreneurship projects.

6.2.1.6 COMPARING STUDENT AND NON-STUDENT PROJECTS

The *project survey* allows for a direct comparison of the student and non-student subsamples of the dataset. Figure 62 shows a comparison of *market maturity, technology readiness* and *technology importance* for the respective subsamples. This comparison reveals some interesting differences between the two groups of projects.

In the *market maturity* graph (top), it can be seen that the students are generally operating in new/emerging markets, whereas the non-students are more active in established markets. Seeing that the student projects are technology driven, it makes sense that the market is not well known at the time of project initiation.

In the *technology readiness* graph, it comes as a surprise that the students generally report a technology readiness, which is higher than the non-student subsample. This is surprising seeing that most of the student teams deal with technologies coming directly from the university labs. It is not directly apparent why the students would report a relatively high technology readiness and unfortunately, a deeper investigation is beyond the scope of the present thesis.

The *technology importance* graph (bottom) is more in line with the expectations as the student subsample generally reports a higher importance of technology than their non-student counterparts do. This makes sense, as the students are explicitly tasked with exploiting new technology in building new businesses.

This comparison indicates that there are clear differences between student projects and non-student projects in terms of the reported characteristics. This is hardly a surprise, as the students are given a very specific task, which is to exploit a technology in an undefined market.

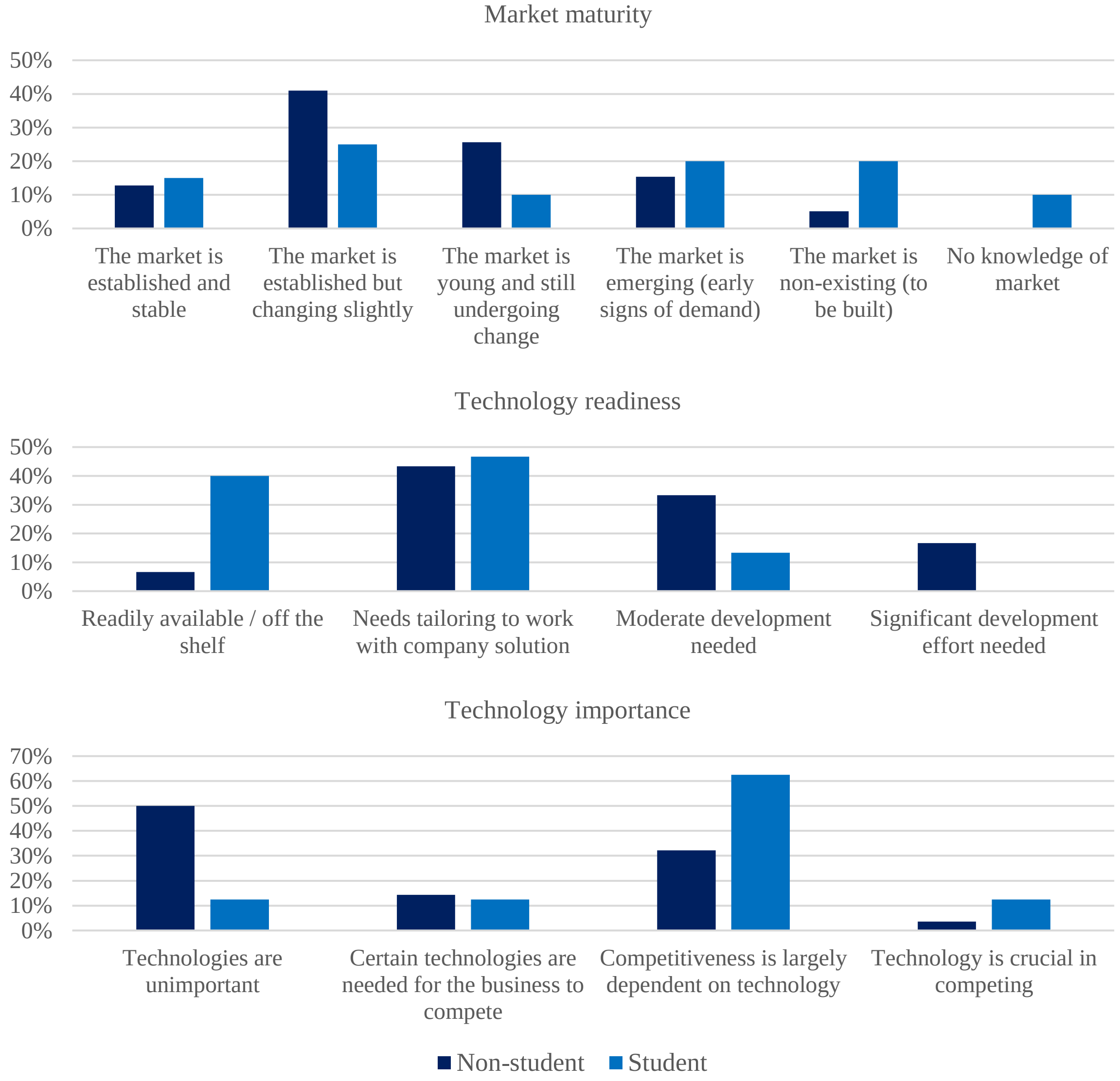


Figure 62: Comparison of student and non-student parts of dataset [own]

This analysis illustrates the direction in which the student projects *bias* the overall sample. This piece of information is important to bear in mind in the coming study of the process database. On the positive side, the analysis also shows that the student and non-student components of the dataset can be isolated if necessary.

Further insights about the differences between the student and non-student subsamples will be provided in the next section. Here, a new approach for analysing the characteristics of projects in the process database is introduced and the first analysis case will be based on a comparison of the characteristics for student and non-student cases.

6.2.2 THE ANALYSIS OF THE PROCESS DATABASE

The first part of this study has focused on understanding the diversity and characteristics of the sample. With this in place, a basis has been created for diving into the process data itself and trying to interpret it. The contextual data on the sample can also be used for comparing the differences seen between various sub-samples. A natural point of departure is to look at the hard-coded categories of the tool (see the section *A new, crowd sourced category system* in chapter 5). For the qualitative analysis of a single case, the network representation can be useful, but if larger amounts of data are to be processed, another type of representation is needed. Figure 63 shows a representation that has been developed for visualising the use of the categories over time.

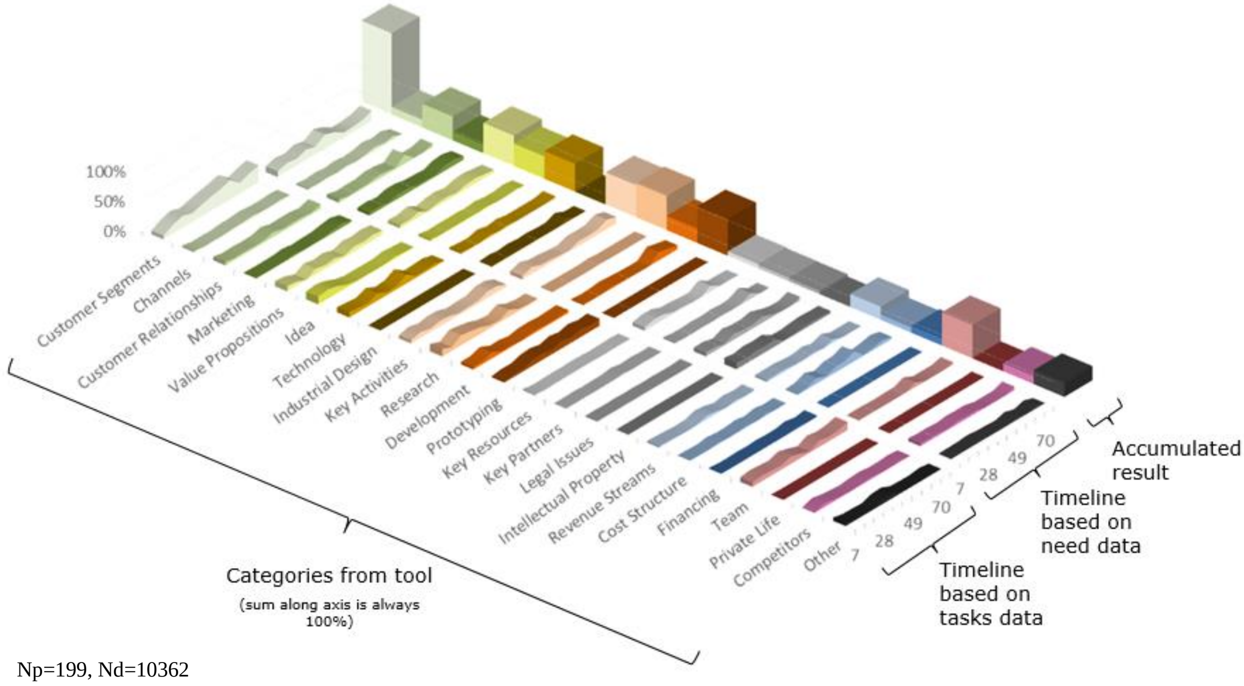


Figure 63: Visualisation of the tool categories over time (days) and accumulated (back row) [own]

The figure shows the category use over time (in days on axis to the right). There are two time lines describing the same time interval. The one in front depicts the amount of activity for *tasks* in each category. This indicates what is actually being worked on at various times. The middle row depicts the amount of *need* activity for each category over the same period. This row indicates what the teams express as needs over time – i.e. what they state as important. The division of the two rows is to enable the identification of any discrepancies between stated importance and actions.

In Figure 63 the timeline data in the *need* and *task* rows is smooth and there are few dramatic peaks or valleys. This smoothing effect is a consequence of the large number of data points (Nd). For subsamples with fewer data points, peaks and areas with no category activity are more likely to occur. This does not necessarily indicate a stronger tendency, but merely the fact that few data points exist at that point in time – the effect of smoothing can be seen by comparing Figure 64 (high Nd) and Figure 65 (low Nd).

Finally, the back row shows the accumulated result for the *task* activity. All rows have been normalised so that a sum across categories for a given time interval will always yield 100%. In the lower left corner, two values are listed; *Np* refers to the number of projects used as a basis for the graph and *Ndp* refers to the number of data points collected.

6.2.2.1 NOTE ON STATISTICAL ANALYSIS

The distributions for category usage have been tested for normality (i.e. if they follow a normal distribution). This test showed that there is currently not a sufficient basis for justifying the use of normal distributions and therefore, parametric statistical tests based such distributions cannot be applied. In this light, non-parametric statistical tests, such as the Mann & Whitney test [Mann & Whitney 1947] have also been is tested as a candidate for calculating probabilities (p-values), but lack of continuity in the distributions means that the results of these tests are misleading. In the continued research, the possibilities for statistically comparing subsets of the data will be further investigated. Also, as the dataset grows, so does the likelihood of more consistent and continuous distributions appearing.

6.2.2.2 DIFFERENCES BETWEEN STUDENT AND NON-STUDENT PROCESSES

To understand the differences in process characteristics between student- and non-student projects in the dataset, the category usage for each sub-sample has been plotted in Figure 65 and Figure 64 respectively. This analysis provides the ability to *methodologically triangulate* (see section 4.2.3.6) some of the findings in section 6.2.1.6, where the differences between student and non-student projects were discussed based on the *project survey.*

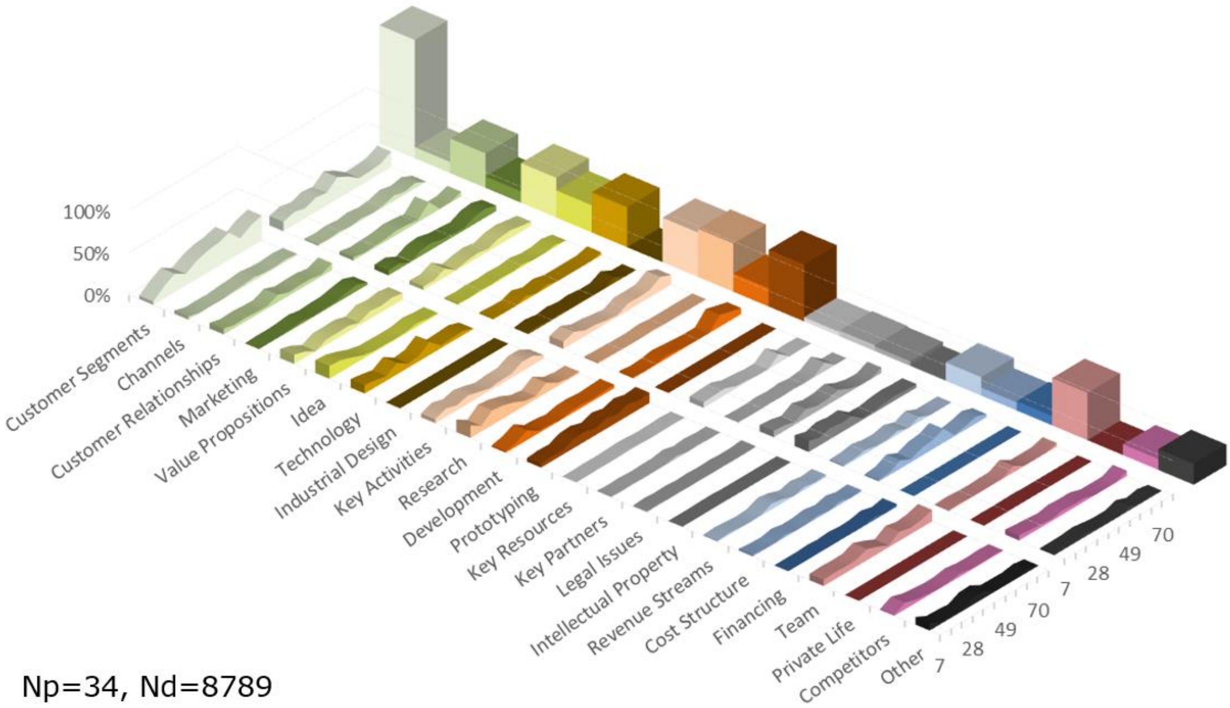


Figure 64: Student projects' category usage [own]

By looking at the figures, a number of differences appear in the category usage. For instance, the student sample has slightly more entries tagged with the *customer segments* tag, indicating that a larger share of the time is spent on identifying the customer and segmenting the market. In the non-student subsample, the (yellow) categories *idea* and *value propositions* are much more prevalent than in the student projects. One interpretation of this could be that the students, who were given a patent and a technology, had a clearer idea of the idea and potential value of the technology, than the non-student project.

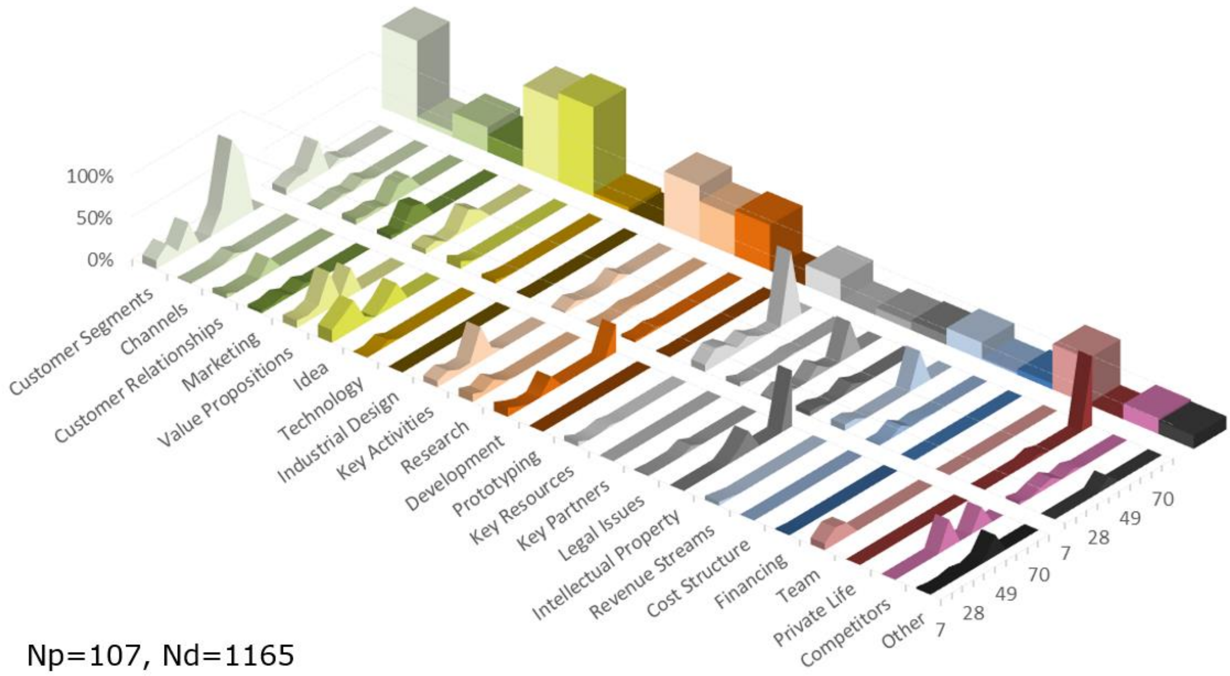


Figure 65: Non-student projects' category usage [own]

Another interesting difference is the differences in the use of the *development* and *prototyping* categories. The former is far more active in the non-student projects, and the latter is more active in student projects. This could be seen as a reflection of the general development stage of the two subsamples. The student projects are generally at an earlier stage of development, where prototypes are necessary for proving the technology. Conversely, the non-student projects are perhaps generally at a more mature development stage, where development, not prototyping is the more important task. This observation somewhat offsets the counterintuitive finding made in section 6.2.1.6., where the student teams generally reported a higher technology readiness than the non-student projects, despite presumably dealing with technologies at a lower readiness level.

When met with such contradictions in the data, one needs to evaluate which source of data is most reliable. In his critique of the trait based view on entrepreneurship, Gartner quotes Yeats: *"How can we now the dancer from the dance?"* [Gartner 1988]. With this, Gartner is implying that there is a need for understanding the entrepreneur by studying the process – not the entrepreneur and his/her traits. In this perspective, the data collected from the process yields a more reliable picture. This assertion is supported by the fact that the process analysis yields *interpretations*, which much more in line with common sense understanding of the phenomenon.

6.2.2.3 THE ROLE OF MARKET MATURITY

As stated, the projects in the sample deal with different levels of market maturity. In this explorative study, it might be interesting to see if there are any noticeable differences between projects in the respective groups. Figure 66 and Figure 67 show graphs of the categories' development over time and accumulated result. To illustrate the link between the subsample and the survey data, the pie chart shown earlier is included.

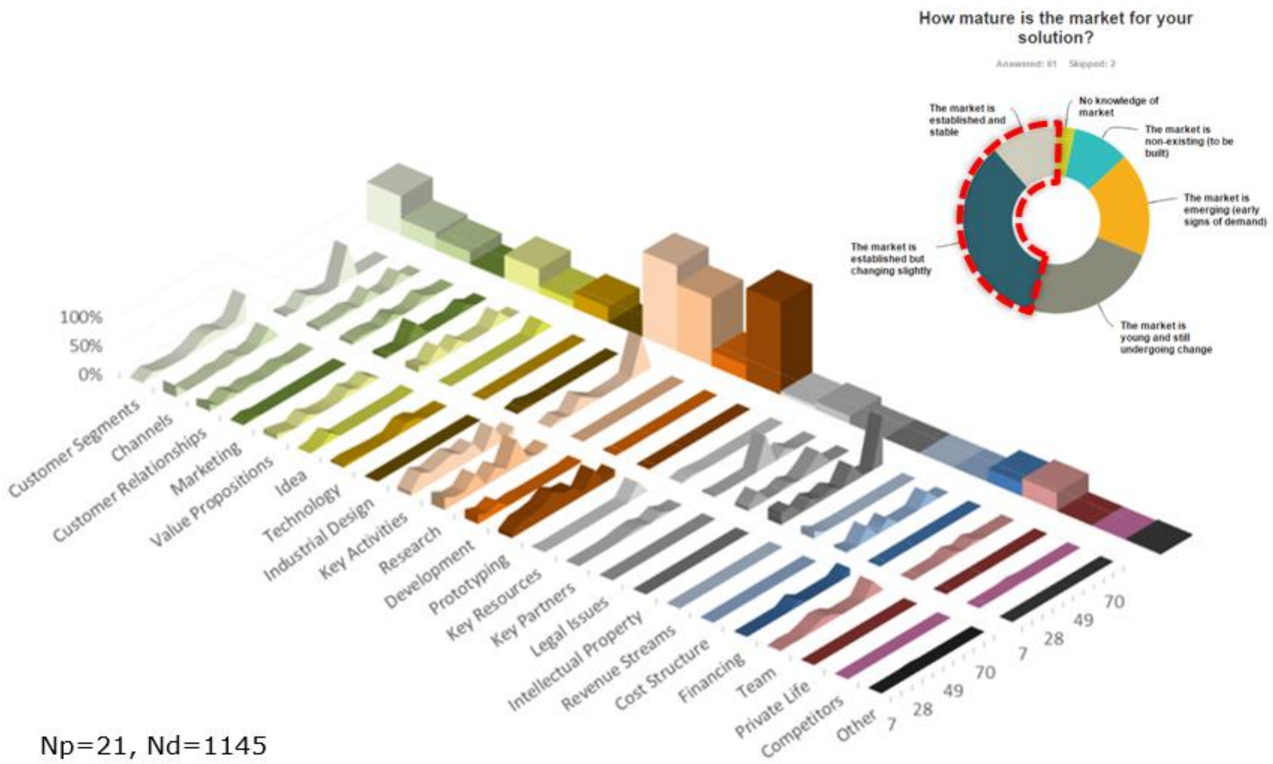


Figure 66: Categories– mature market [own]

On visual inspection, there seems to be a large difference in the accumulated use of categories. Tasks relating to *Customer segments* and *Idea* are far more prevalent in the *immature market* than in the *mature market.* The same goes for the *Team* category, which is used to a much greater extent in the projects dealing with *immature markets.* Conversely, the *mature market* subsample is very active within the *research*, *development* and *prototyping* categories.

The theories introduced earlier offer various ways of understanding the differences in the characteristics of the processes. In the *constructivist perspectives* of [Bruyat & Julien 2001] and [Sarasvathy 2008], the opportunity is not a pre-determined thing to be grasped and exploited by the entrepreneur – as opposed to the Schumpeterian perspective. Rather, the opportunity is created in a dialogue between the venture (the *"I"*) and the new value creation *(NVC)*. The prevalence of the *idea* and *value propositions* categories in the tasks executed early in the process indicates that the team is indeed engaged in such a dialogue. In fact, the market-related categories (e.g. *customer segments* and *marketing*) are more active at the later stages of the process. This can be seen as a confirmation that the entrepreneurs working in the immature market start with themselves, their knowledge and their immediate surroundings when building the business – very much in tune with Sarasvathy's *effectuation* theory.

On the other hand, the *idea* and *value proposition* categories are much less prevalent in the *mature market* ventures. Instead, the main task activity is within *research*, *development* and *prototyping*. This lends credence to the Shanian notion of new *means-end relationships* [Shane & Venkataraman 2000] being a defining factor for entrepreneurship – even if the market is stable and known.

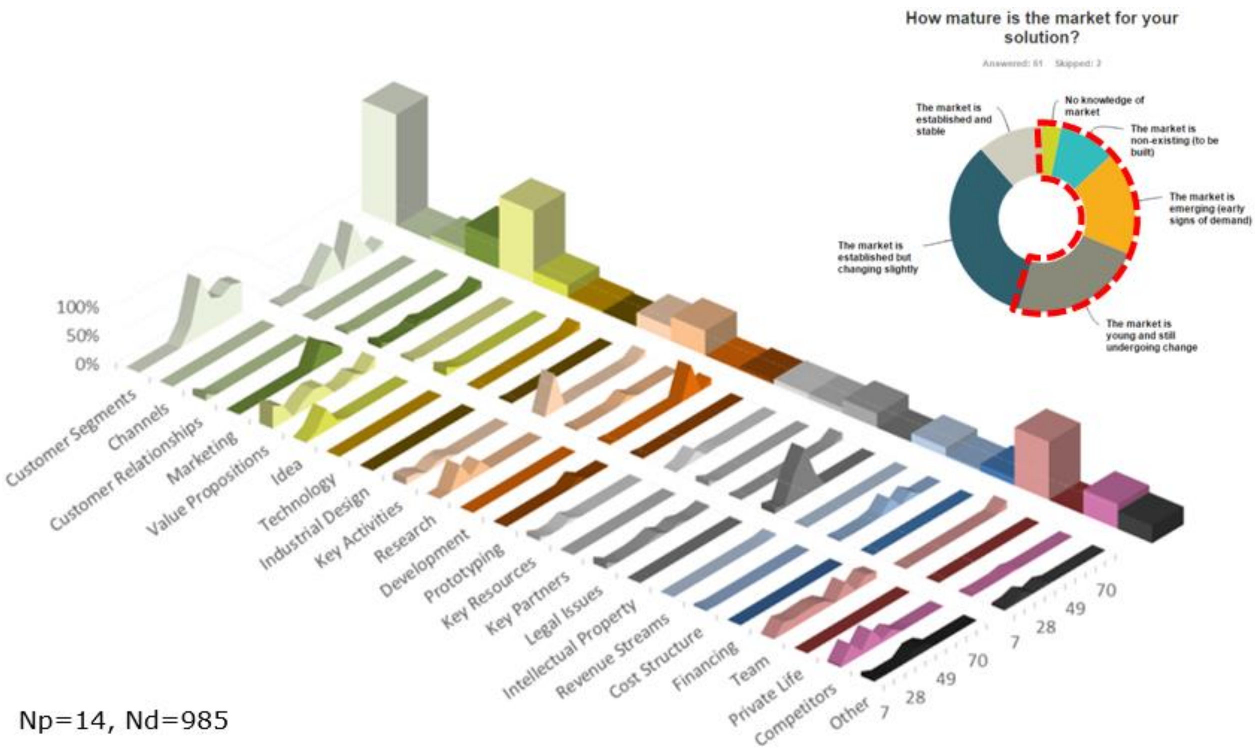


Figure 67: Categories – immature market [own]

6.2.2.4 THE ROLE OF TECHNOLOGY

In chapter 3, it was argued that the role of technology in entrepreneurship processes was under-researched. Having now established a substantial dataset on entrepreneurship processes as well as the data necessary to classify the samples, in terms of technological dimensions, the analysis now proceeds to elucidate the influence of technological risk on the process.

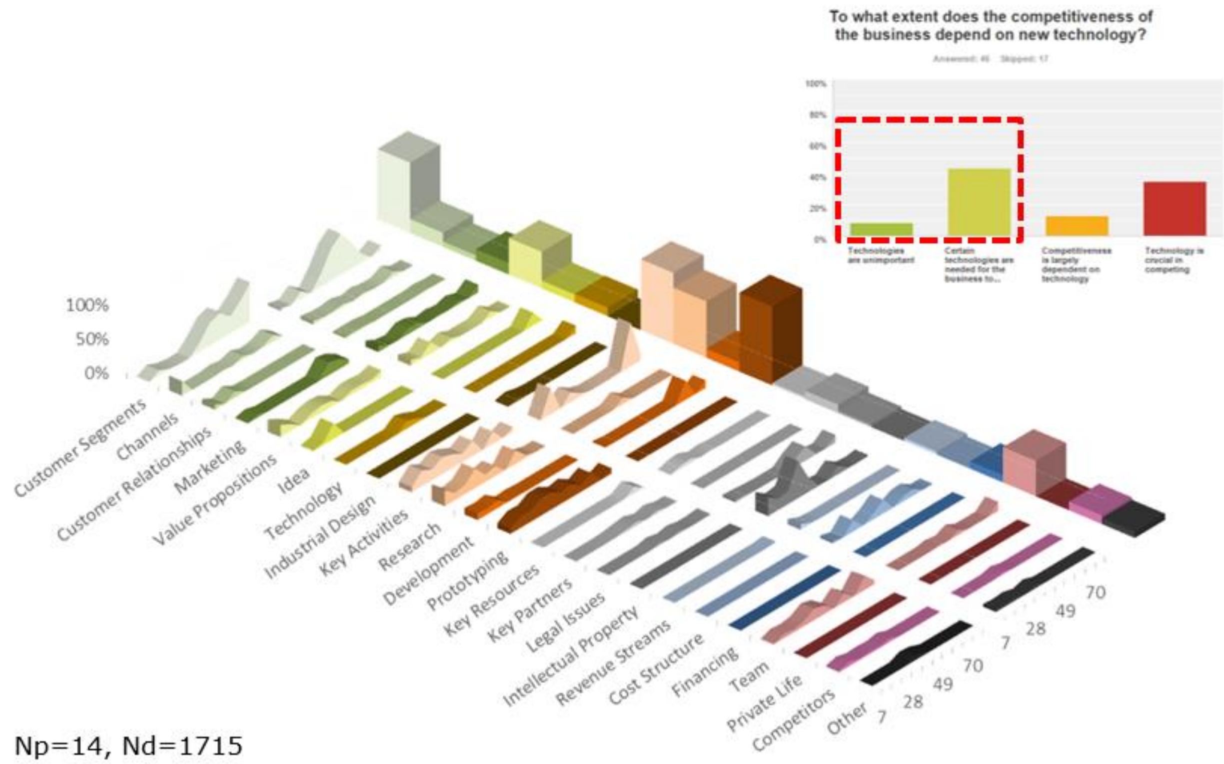


Figure 68: Categories – technology not important [own]

As stated, the *technology need value* (*TNV*) is closely related to the *project survey* question regarding technology importance. As in the previous section, the sample has been divided into two subsamples – one where technology is important to the venture and one where it is not. Figure 68 and Figure 69 show the two corresponding graphs.

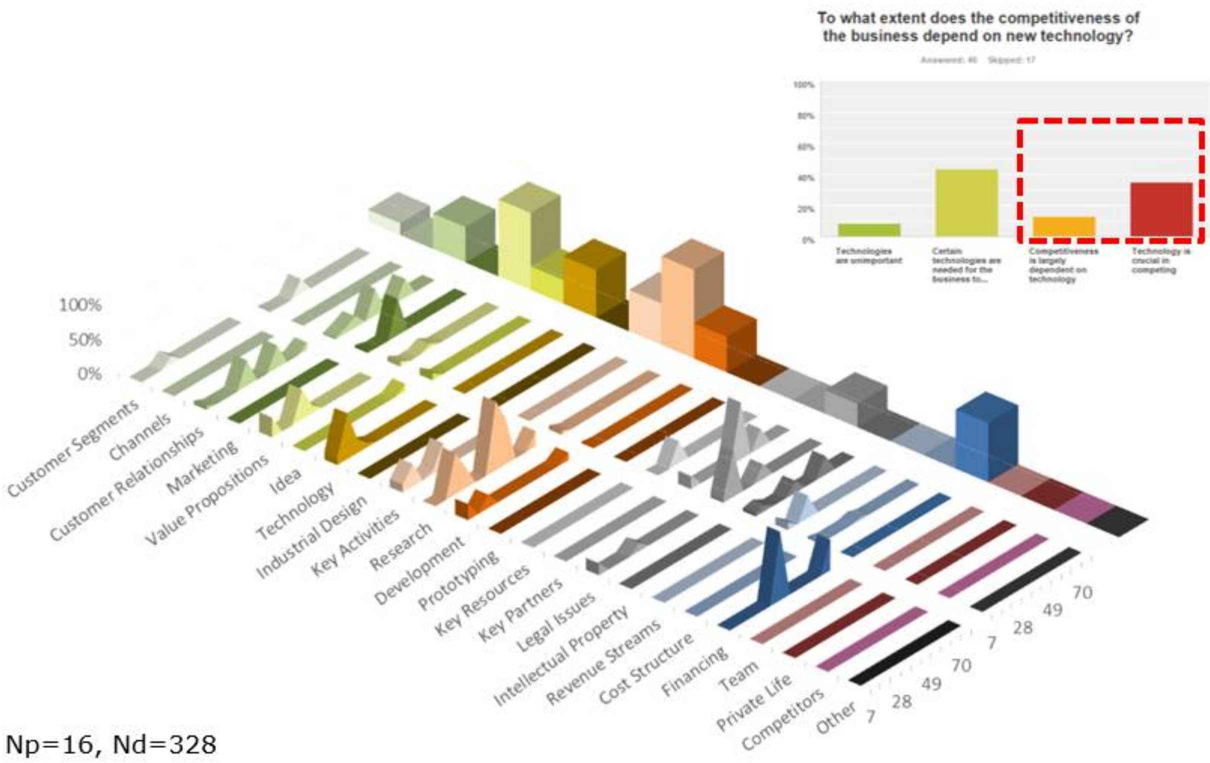


Figure 69: Categories – technology important [own]

When looking at these two figures, one thing quickly becomes apparent; namely, the big difference in number of data points (*Nd*). Because of this difference in sample size, one should be careful not to proceed to quickly to conclusions based on visual inspection.

Not surprisingly, the *technology* category is more active in the subsample where technology is considered important. Similarly, *research* and *development* are found to be more prevalent in this sample than in its less technology-centric counterpart. The *Idea* and *value propositions* categories are also significantly higher.

The projects where technology is less important have spent more time on activities within the *customer segments* category indicating that in general, these projects have a greater need for clarifying who the customer is. Conversely, the projects where technology is important generally spend a limited amount of time on *customer segments.*

One surprising feature in the graphs shown is the fact that the teams where technology is important have no activity within prototyping. This is very peculiar as projects dealing with low technology readiness levels are the ones that can gain the most from prototyping activities. The author cannot offer a substantiated explanation for this strange feature aside the very limited amount of data points in the sample. More data is needed before a proper conclusion can be drawn.

An equally surprising finding is that the level of activity in *prototyping* is high in the part of the sample where technology is less important. As this part of the sample has more data points, one can be more confident in the feature being representative. However, when investigating the root causes for this counterintuitive feature, it was found that the subsample for low technology importance had one project (out of the total 14), which accounted for 30% of all the data points. Unlike the rest of the projects in the subsample, this project has a large share of tasks related to prototyping (~22%) – by far the largest share of all projects in the dataset. Consequently, this project has a disproportionately large influence on the sample and it is removed in the continued analysis. Figure 70 shows the difference in the graph after the project has been removed. This example shows how the influence of single projects with many data points (Nd) can be substantial despite the growing number of projects and data points.

To understand technological risk, one also needs to consider the maturity of the important technology. Figure 71 and Figure 72 show the differences in category activities for the subsamples dealing with mature and immature technologies respectively.

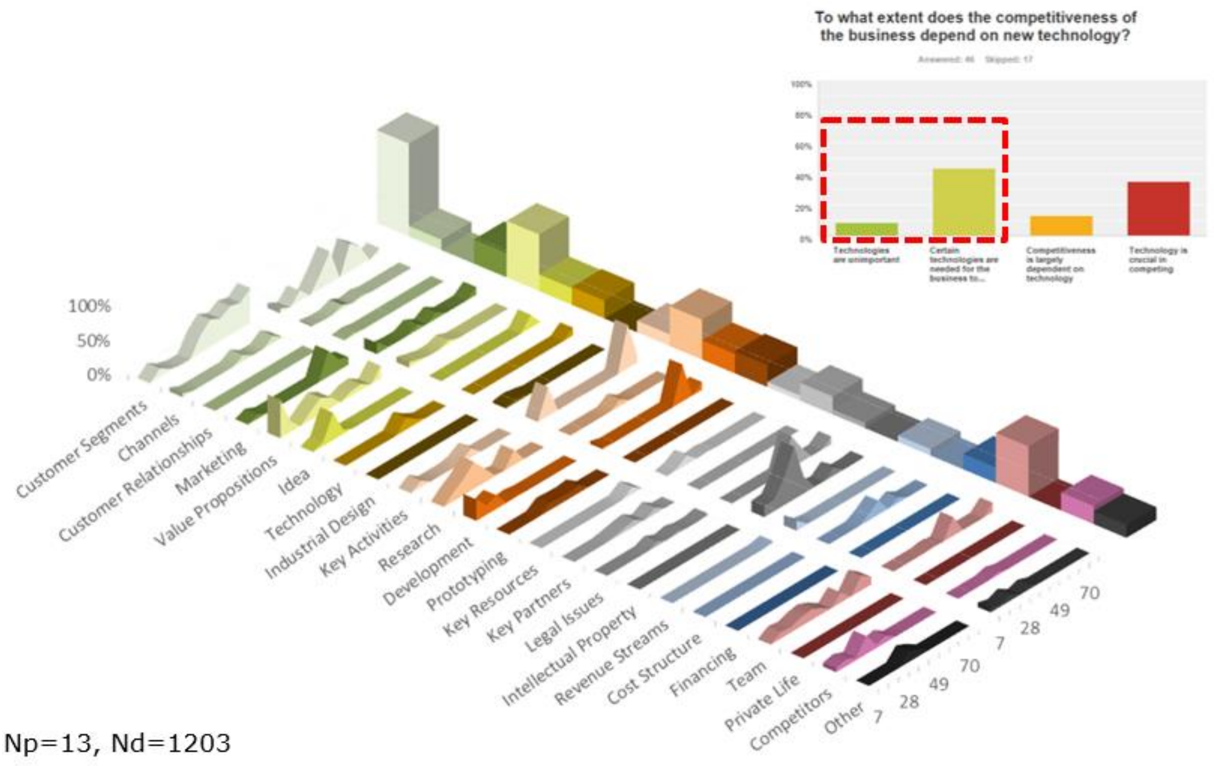


Figure 70: Categories – technology not important, with large project removed [own]

Again, one of the theoretical frameworks described can help in understanding the variance observed in the sample. In Mankins' technology risk matrix *the consequence of R&D failure (Cf)* is calculated as a product of the required progression (the delta) of the *technology readiness level* and the *technology need value.* The cases where the technology is mature and/or of grave importance, exhibit a large share of activities related to technology risk mitigation – *research, development, technology* and *prototyping.* In other words, the data presented clearly shows that the process is strongly affected by Mankins' technology risk components.

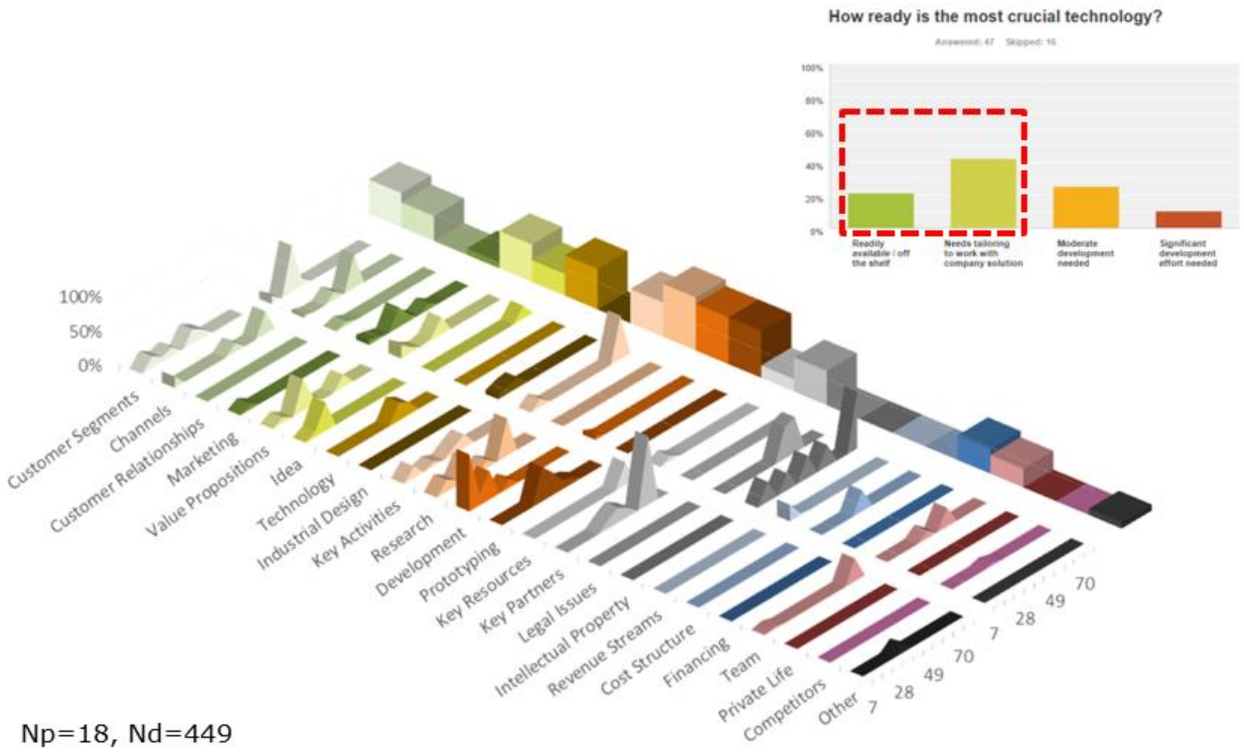


Figure 71: Categories – technology mature [own]

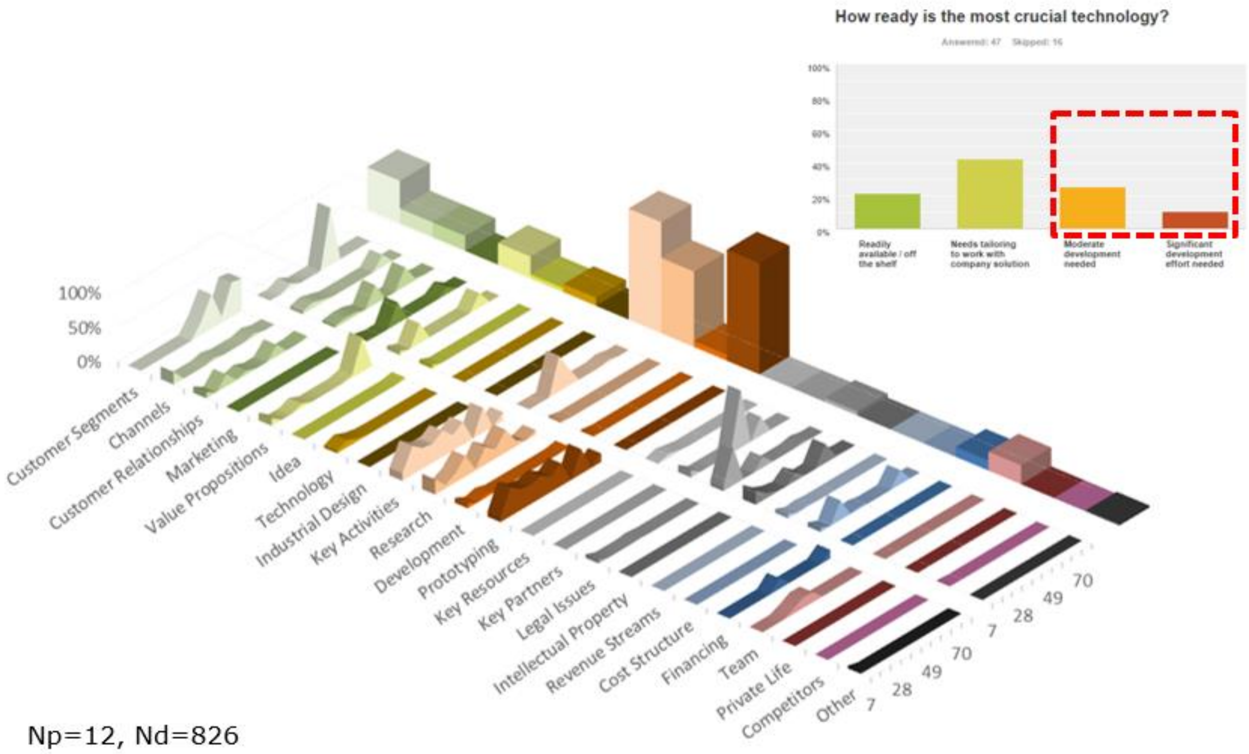


Figure 72: Categories – technology immature [own]

As explained earlier, the last component of the *technology risk* matrix – R&D3 – is not properly covered in the current project survey questions. To fully understand the influence on technology risk on the phenomenon, relevant questions will be added to future versions of the survey (beyond this thesis).

Despite missing one component of the *risk matrix*, the data clearly shows that the processes involving technological risk are distinct from their less technology-laden counterparts.

6.2.3 LIMITATIONS OF STUDY 1

When reading the conclusions stated above, one should be aware of a number of limitations. The issues pertaining to *sampling* and *generalisability* have already been discussed at length, but a few other issues have not yet been treated.

First and foremost, the study relies entirely on the predefined data structure in the tool and its categories. Although designed to interfere as little as possible with process (see chapter 5, page 85), the two cannot be separated and *reactive effects* are difficult to estimate. One way of strengthening the trustworthiness of the results would be to triangulate the findings methodologically (use another method for data capture). One way of doing this is to conduct a study based on the unstructured/qualitative data (similar to study 3) and see if the same tendencies appear.

Secondly, one should bear in mind that the teams themselves choose which categories are used and how these categories are interpreted. One should not confuse this *emic* interpretation with the researcher's interpretation (*etic*). In other words, the user's interpretation of a given category is not necessarily the same as the interpretation by the researcher and the two should not be confused.

6.3 STUDY 2: TRACKING EFFECTUATION PRINCIPLES IN ENTREPRENEURSHIP PROCESSES

Sarasvathy's studies [Sarasvathy 2008] on the cognition of experienced entrepreneurs were based on *think-aloud studies*, where the entrepreneur was given a fictional business idea and asked to develop it further. In the subsequent hours, the entrepreneur would then verbalise his (the respondents were exclusively men) thoughts and strategies for developing the business. Follow-up studies have subsequently been conducted [Nielsen & Lassen 2011; Wiltbank et al. 2006], but none have been identified that are based on direct observation of entrepreneurial activities (process). To address this, the coming section will investigate the role of *effectual principles* in the processes captured in the tool database. Specifically, the study will attempt to verify Sarasvathy's finding that experienced entrepreneurs are more likely to exhibit *effectual* behaviour.

To verify this, the *deductive study* type in the EPR Methodology will be used (see the section *The emergence of a semi-automated interpretive methodology* in chapter 5) to track the principles in the data. The *team member survey* holds information on the experience of each team, which means that this can be used as the *independent variable*. The *dependent variable* will be the extent to which the team engages in *effectual* behaviour.

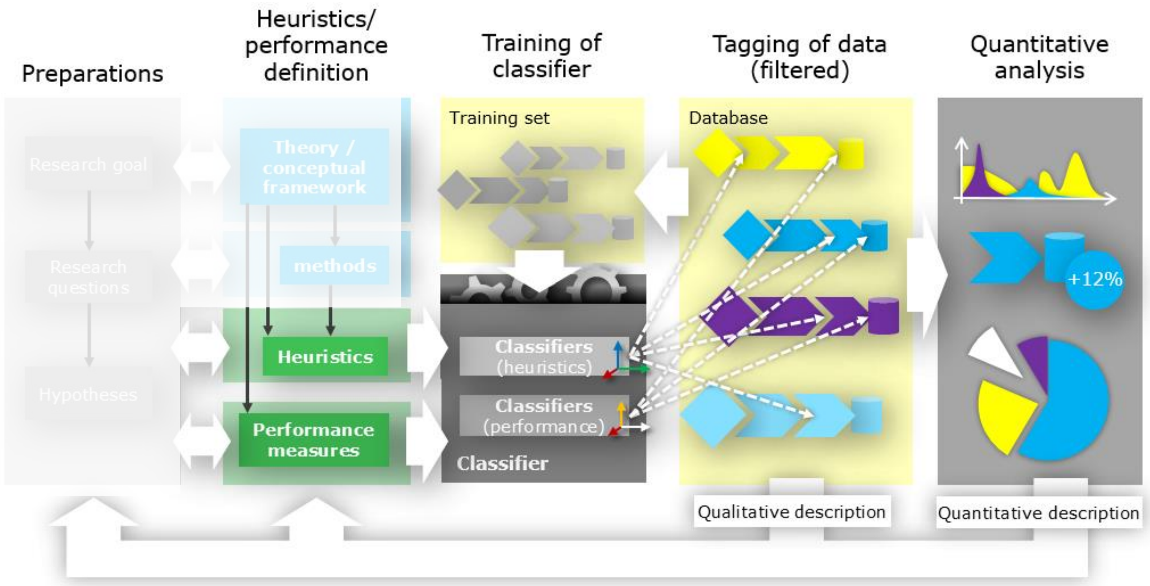


Figure 73: The research methodology of the study – EPR methodology Deductive study [own]

6.3.1 HEURISTICS DEFINITION

As the principles are equivalent to heuristics, they form an excellent basis for training a classifier. In Figure 73, the *deductive study type* is shown with a slight modification. As the heuristics are already known, the preparations and higher-level theoretical considerations can be bypassed.

6.3.2 TRAINING OF CLASSIFIER

The process data from the tool database was subsequently used for building a training set. The training set included all 5 *effectual* principles along with their *predictive* counterparts, which are also explicitly stated in most standard materials on effectuation (e.g. http://www.effectuation.org/sites/default/files/documents/effectuation-3-pager.pdf). These heuristics (10 in total) were then used to tag a total of 3500 random sentences from the database.

As certain heuristics were only used sparsely and a great deal of ambiguity was found to exist between them, a decision was made to group the principles in two overall tags – one for *effectual* behaviour and one for *predictive behaviour.* The text data was subsequently *vectorised* using a uni- and bigram *vectoriser.* The principles of *vectorisation* of text data are treated at length in study 3 (the *vectoriser* used in this study is similar to the v12 vectoriser mentioned on page 148).

With the tagged and *vectorised* data in place, various classifier types were tested for precision, using part of the training set as a test set. A neural network classifier (the *"perceptron"*) [Pedregosa et al. 2011] was found to be most precise with an average *precision* of around 60%. This level of precision is somewhat lower than the ideal 80+%, but with the current data set and the time available, it was not possible to achieve a higher precision. The problem with the lack of *precision* is that some elements in the dataset might not be tagged despite describing *effectual* behaviour. One redeeming characteristic of the trained classifier was that another important metric – *recall* – was quite low, meaning that the classifier rarely classified elements incorrectly.

Figure 74: Computed vs evaluated levels of effectual behaviour. The data has been sorted based on the rating given by the respondent. [own]

As the real-world implications of these performance numbers were difficult to grasp, an alternative validation step was planned: Here, the performance of the classifier, in terms of number of effectuation tags per project, was compared to a subjective evaluation of *effectual* activity levels in the same projects. To this end, a respondent who had followed the projects closely was asked to rate the degree of *effectual* behaviour in each project. Figure 74 shows the comparison of this estimate (dots) to the predictions made by the classifier (triangles and squares) for the same projects. As seen in the figure, the classifier generally managed to compute levels similar to those predicted by the respondent. Having said this, the precision of the classifier should still be improved in future versions, by way of more training data and perhaps the use of more advanced classification algorithms.

6.3.2.1 TAGGING OF DATA AND ANALYSIS

The classifier was subsequently used for processing the entirety of the database and identifying occurrences of *effectual* and *predictive* behaviour. In total, 199 projects were tagged. Figure 75 shows 10 of the most detailed projects, distributed on the vertical axis and the occurrence of *effectual* and *predictive* tags over time on the horizontal axis. To enable comparison, the tags have been collected in weekly cohorts, starting from the day the project was initiated in the tool. The size of the dot is an indication of the number of *effectual* tags given for that time interval (week).

Figure 76 shows the percentage the data points that are tagged with *effectual* and *predictive* tags, respectively.

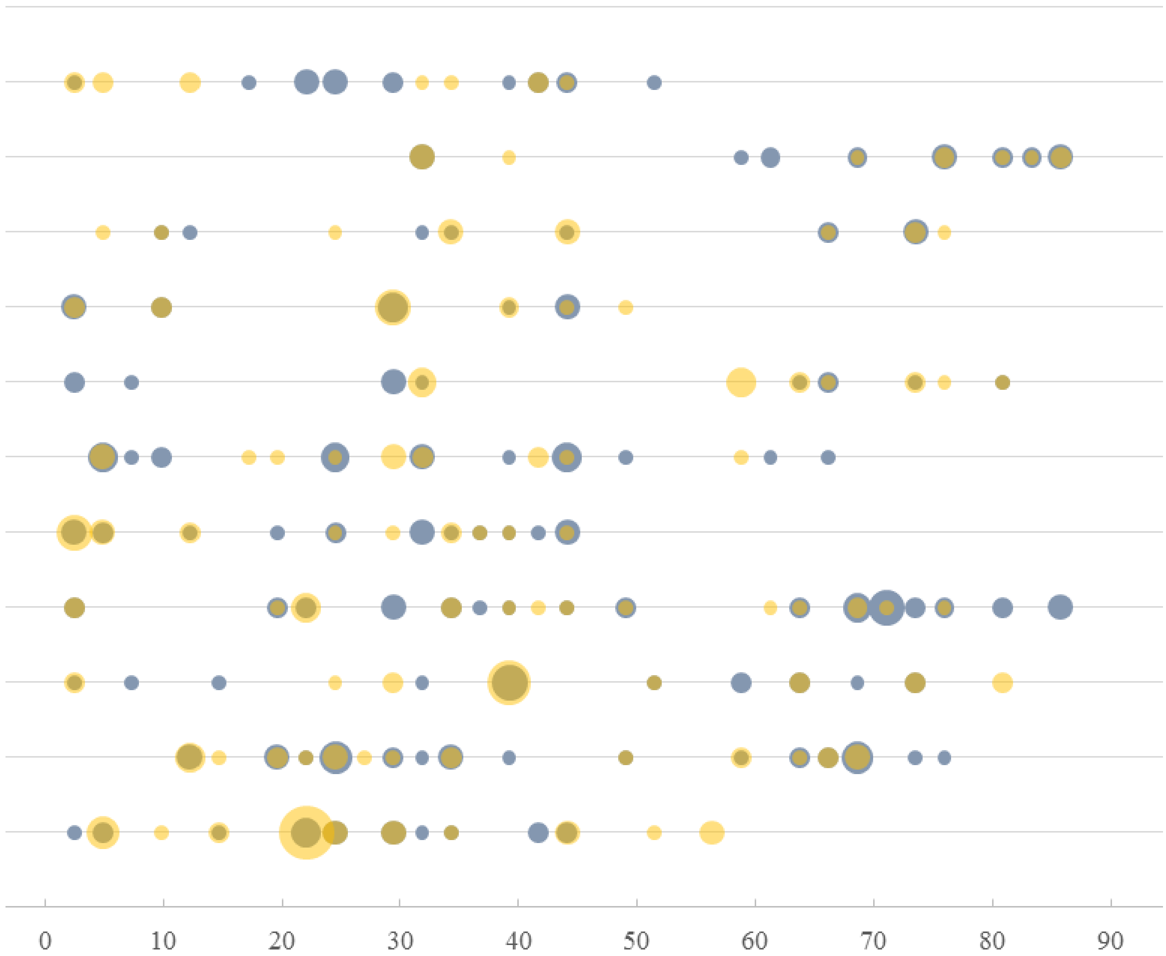


Figure 75: Effectual (orange) and predictive (blue) behaviour tagged using classifier [own]

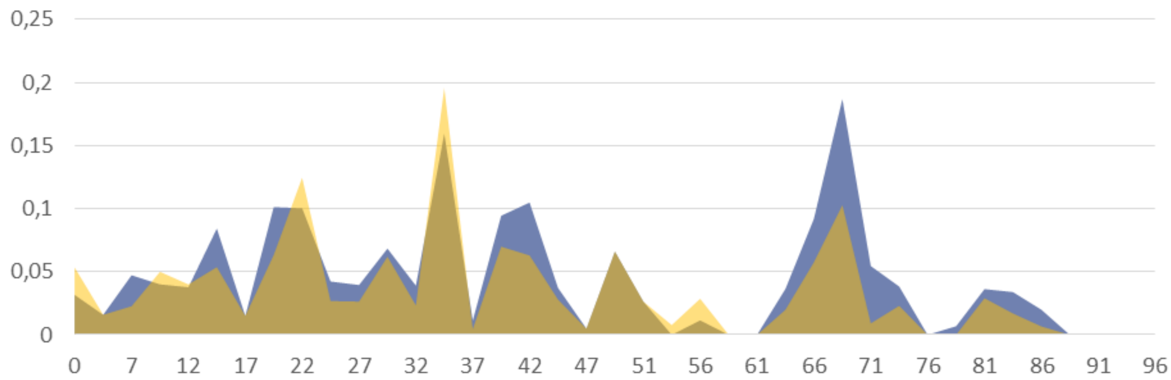


Figure 76: The average share of effectual (orange) and predictive (blue) tags over time. [own]

These two figures do not show any clear tendencies in the use of the tags. One tentative conclusion seems to be the fact that the *predictive* and *effectual* tags seem to follow each other. This indicates that the two dimensions of the entrepreneur's cognition complement rather than oppose each other.

6.3.2.2 ENTREPRENEURIAL EXPERIENCE AND EFFECTUATION

The purpose of this study is to use the process data set to verify the proposed relation between entrepreneurial experience and the use of *effectual* cognitive strategies. The contextual data from each project in the database enables a quantification of the team's startup experience. Specifically, the team member survey asks each team member two questions, relevant for determining the level of experience; one related to how many startups the team member has been part of and one relating to the maturity reached for the most successful of these startups (on an ordinal scale, ranging from *hobby project* to *initial public offering or "IPO"*). The first question is used as a basis for the analysis below.

The structure of the data set enables a direct link to be drawn between the level of experience in the team (*independent variable*) and the prevalence of *effectual* and *predictive* activities.

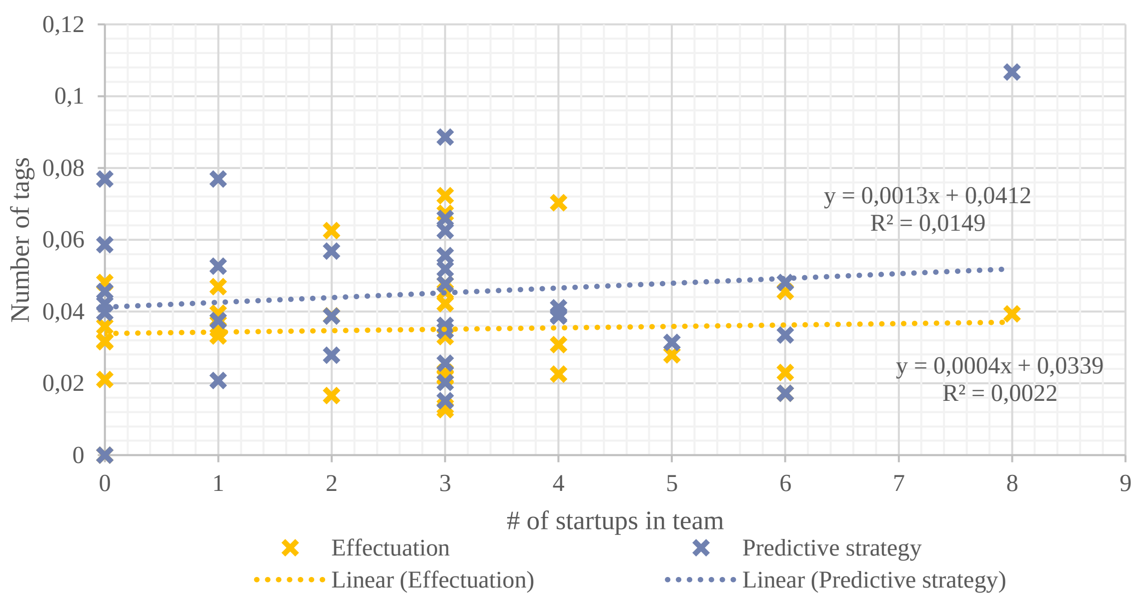


Figure 77: Scatter data for project teams' startup experience (# of startups in team) and number of tags. Linear trend lines are plotted to indicate tendencies in the data. [own]

Figure 77 shows a scatter plot of the number of startups each team has been part of (horizontal axis) versus the number of tags (*effectuation* and *predictive*). To indicate any trends, the plot also shows linear trend lines for both tag types.

From the figure, it is clear that no strong correlation exists between the number of startups and the number of *effectual* and *predictive* tags. An R^2 rating of close to one would indicate a strong trend, but the values are very low, indicating that there is no strong correlation. There is nothing speaking for (or against) Sarasvathy's proposed relation between experience and use of *effectual* strategies.

The study presented here cannot verify or falsify the predictions made by Sarasvathy. The reason for this is that the number of data points featuring both startup experience information and *effectual / predictive* tags is too limited. The study does however show the feasibility of all the steps that need to be taken in conducting such a deductive study based on the EPR Methodology. As the data set grows, the confidence level in regressions will hopefully grow to accommodate the verification of other theoretical predictions.

6.3.3 LIMITATIONS OF STUDY 2

This deductive study has shown the process of using *natural language processing* and *machine learning* to track heuristics in the qualitative data produced by the tool. The ambiguity of the study results do however warrant a discussion on the limitations of the *methodology* and its application in the study.

The classifier, which was trained in the study, failed to meet the goal of a >80% precision. Another, practical validation step was instead used to gauge the ability of the classifier to capture relevant data. This step was necessary due to two factors: One, which has already been treated, is the lack of a sufficient amount of training data (not enough sentences). The second factor, which has not been mentioned, is the simple fact that the qualitative data might simply not hold the semantic features, which characterise the heuristic (class).

This leads to another more general issue: Whether or not the theory for the heuristic is actually *theoretically valid* in terms of the studied phenomenon. In other words, the reason why few instances of the heuristic were found could relate to the fact, that the heuristic is not a relevant concept to the phenomenon at hand. Another interpretation is that the *descriptive validity* of the methodology is weak and that the features necessary to describe the theoretical components are not being captured.

6.4 STUDY 3: ABDUCING CONCEPTUAL COMPONENTS FROM DATA

In chapter 3, the search for a theoretical understanding of technology entrepreneurship processes yielded no useful result. It was realised that for any theoretical understanding to emerge, a better empirical grounding was needed and in extension of that: Better tools for doing empirical research within the field of entrepreneurship. With the EPR tool and methodology, such a tool now exists and the previous two studies have shown that it can be used in gaining valuable insights about entrepreneurship processes.

In this 3rd study, the original theoretical weakness is addressed, as the empirical data captured by the EPR tool is used for abducing a new conceptual framework for technology entrepreneurship processes. The goal is that this framework can form the basis for development of strong support for the processes in Danish maritime ventures.

In the study, the *abductive study design* from the EPR methodology is used to identify patterns in the qualitative data and build a theoretical understanding of these. The components of the study are shown in Figure 78. One could have opted for using *grounded theory* [Glaser & Strauss 1967; Charmaz 2006] to support the study, but seeing that the scope of the data is so large, this is simply not feasible by itself. Instead, the *abductive study design* uses the *abductive* principles of *grounded theory* and couples them with recently developed *natural language processing* and *machine learning* techniques.

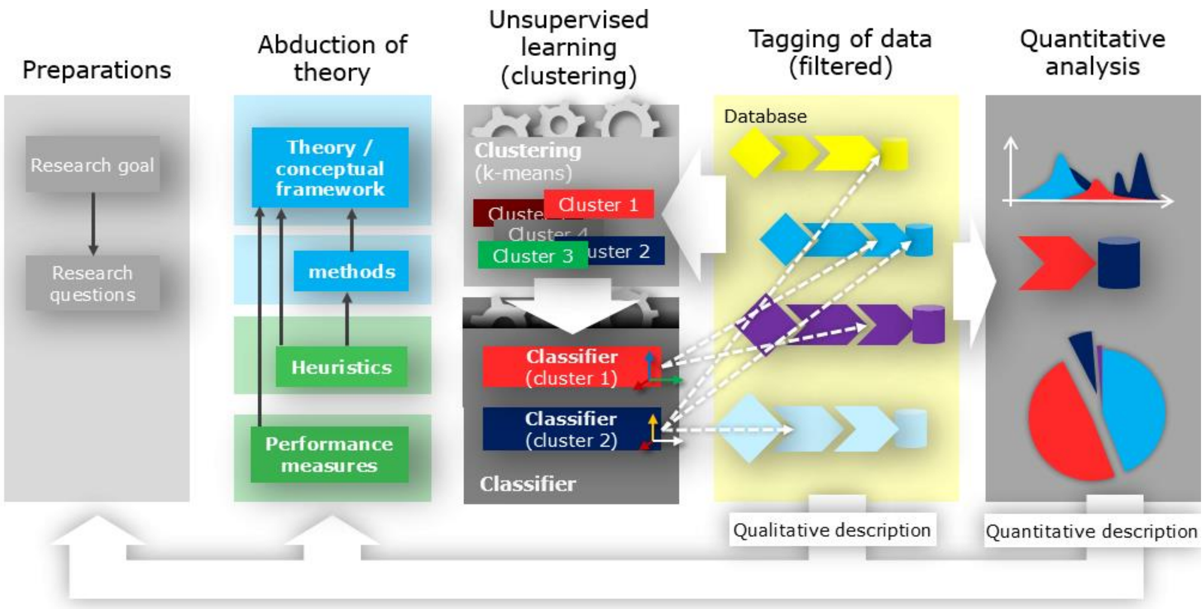


Figure 78: The abductive study design [own]

This study has no *inductive* perspective and aside from the *conceptual framework* intrinsically imposed by the tool architecture (see chapter 5), no theoretical starting point will be provided for the study. In short, the purpose is to let the qualitative data speak for itself. This approach does not dismiss the explanatory power of existing theory. Indeed, if properly founded existing theories for the phenomenon should be attainable from the analysis.

6.4.1 DISCRETISATION AND VECTORISATION

The *research design* utilises the software package *Scikit Learn* (www.scikit-learn.org) for processing and clustering of the natural language data. Clustering algorithms are normally based on geometric variables such as distances and point densities. Words in (sometimes long) paragraphs are not directly usable in such clustering algorithms. To create a manageable format, the paragraphs first need to be split into sentences. This is done using a so-called *sentence tokeniser*, which is essentially a computer program (from www.nltk.org) that can determine when a new sentence has begun. This discretisation step isolates the sentence as unit of analysis. The author has attempted to use whole paragraphs or even single words for clustering, but the sentence format has yielded the most useful results.

The second step is to *vectorise* the sentence, so that it can be compared to other sentences. The *vectorisation* entails giving each word in the entire corpus of data an index. When a sentence is vectorised, a vector is created with zeros in all places except at the indices of the words contained in the sentence. The *vectoriser* (another program) can be instructed to use single words or combinations of words called *n-grams* – e.g. "*business*" (a unigram), "*business model"* (a bigram) and "*business model canvas"* (a trigram). *Vectorisation* schemes using *bigrams* and higher order *n-grams* have the advantage of also capturing sentence structure. In a *unigram vectoriser*, common combinations of words are not registered – also, the order of words in a sentence is lost – e.g. the difference between "*ship new build*" (a noun) and "*build new ship*" (an imperative). In *bi-* and *trigrams*, the word order is not lost.

In the present study, two separate *vectorisers* were used – one using uni- and bigrams (called "*v12"*) and one using bi- and trigrams (called *v23*). The reason for this is the fact that the two approaches yielded two sets of clusters, which were found to complement each other. This will be discussed in more detail below.

When configuring a vectoriser, one must also bear in mind that a corpus of data can contain many unique words, which only occur once or twice. These words will not help in building the clusters and for that reason a *minimum term frequency* is set. For this study, a minimum frequency was set at 0,4% meaning that the term has to be mentioned in at least 0,4% of the sentences in the dataset. Also, some words such as *"and"* and *"is"* appear very often and provide no extra features for differentiating sentences. These are called *stop words* and are automatically removed by the program.

6.4.2 UNSUPERVISED LEARNING: CLUSTERING SENTENCES

When the sentences have been vectorised, they can be compared and clustered. The sentence vectors essentially describe a position in the n^{th} dimensional space (n being the number of indices in the vector). The distance between two points (p1 and p2) can be calculated using *Euclidian* distances:

$$d_{p1-p2} = \sqrt{(x_{12} - x_{11})^2 + (x_{22} - x_{21})^2 + (x_{32} - x_{31})^2 + \ldots + (x_{n2} - x_{n1})^2}$$

The maximal distance in this n-dimensional space is $\sqrt{n}$, but as most sentences are mostly zeros, the distances are typically in the order of magnitude of 1. Various clustering algorithms have been tested for the present study (herein *k-kmeans*, *mean shift*, *spectral clustering* - all included in the Scikit Learn package) and the algorithm producing the most meaningful results was found to be the *Density-Based Spatial Clustering of Applications with Noise* (DBSCAN) approach [Ester et al. 1996]. This algorithm finds local areas with a high point density and provided that a certain number of core points - $min_{samples}$ - are found, the algorithm proceeds to find other samples that are in close proximity. This proximity is defined by a minimum *Euclidian distance* between core points and new points – determined by the *epsilon* parameter. If a new point is added to the cluster, the algorithm proceeds and performs the same evaluation again – this time using the new point as a starting point. In short, the algorithm starts with a core of dense points and from there, it grows the cluster to include nearby points.

For the present study, the DBSCAN parameters were adapted to fit the differences in input data caused by the use of different *vectorisers.* Specifically, as the *v23 vectoriser* yields fewer terms (lower *n*) than the *v12 vectoriser,* a lower term frequency is allowed. The threshold for minimum number of core points for a cluster is also reduced. Finally, a lower *n* means a shorter *Euclidian* distance between data points. For this reason, epsilon is also set at a lower level. The model parameters are listed in Table 16. In general, the parameters were chosen to arrive at a manageable number of coherent clusters.

	Vectoriser parameters		***DBSCAN parameters***	
Vectoriser name	*n-gram range*	$tidf_{min}$	$min_{samples}$	*epsilon*
v12	1-2	0.004	35	0.7
v23	2-3	0.002	25	0.6

Table 16: Vectoriser and DBSCAN parameters

Figure 79 and Figure 80 present an initial description of the clusters created by the DBSCAN algorithm on the data *vectorised* using the *v12-* and *v23 vectorisers,* respectively. The representation used was developed to illustrate relations between clusters. In it, the clusters are listed on the horizontal axis and the word features relating to each cluster are highlighted in warmer colours. The warmer the colour, the more significant the semantic feature is to the cluster. The figure is populated by first adding the main contributing features of cluster 0 to the vertical axis. When no more features are available for a cluster, a thick white horisontal line is plotted, indicating that the features below it belong to the next cluster. The process is then repeated for the second cluster – unless its features have not already been added – in which case, a "hot spot" will appear off the diagonal. These off-diagonal hotspots indicate overlap between the features used by the clusters. For instance, in Figure 79, the feature (word) "*contact*" is a feature in both cluster 5 and 17 indicating a potential overlap between the clusters.

To really understand if the clusters make sense and/or overlap, a qualitative inspection is required of the sentences within each cluster. Note, that the cluster with the number "*-1*" shown in both figures is a *noise* cluster produced by the algorithm and as such it does not represent any patterns within the semantic data. By inspecting the sentences linked to each cluster, it was possible to find clusters of consistent meaning and determine relations / overlap.

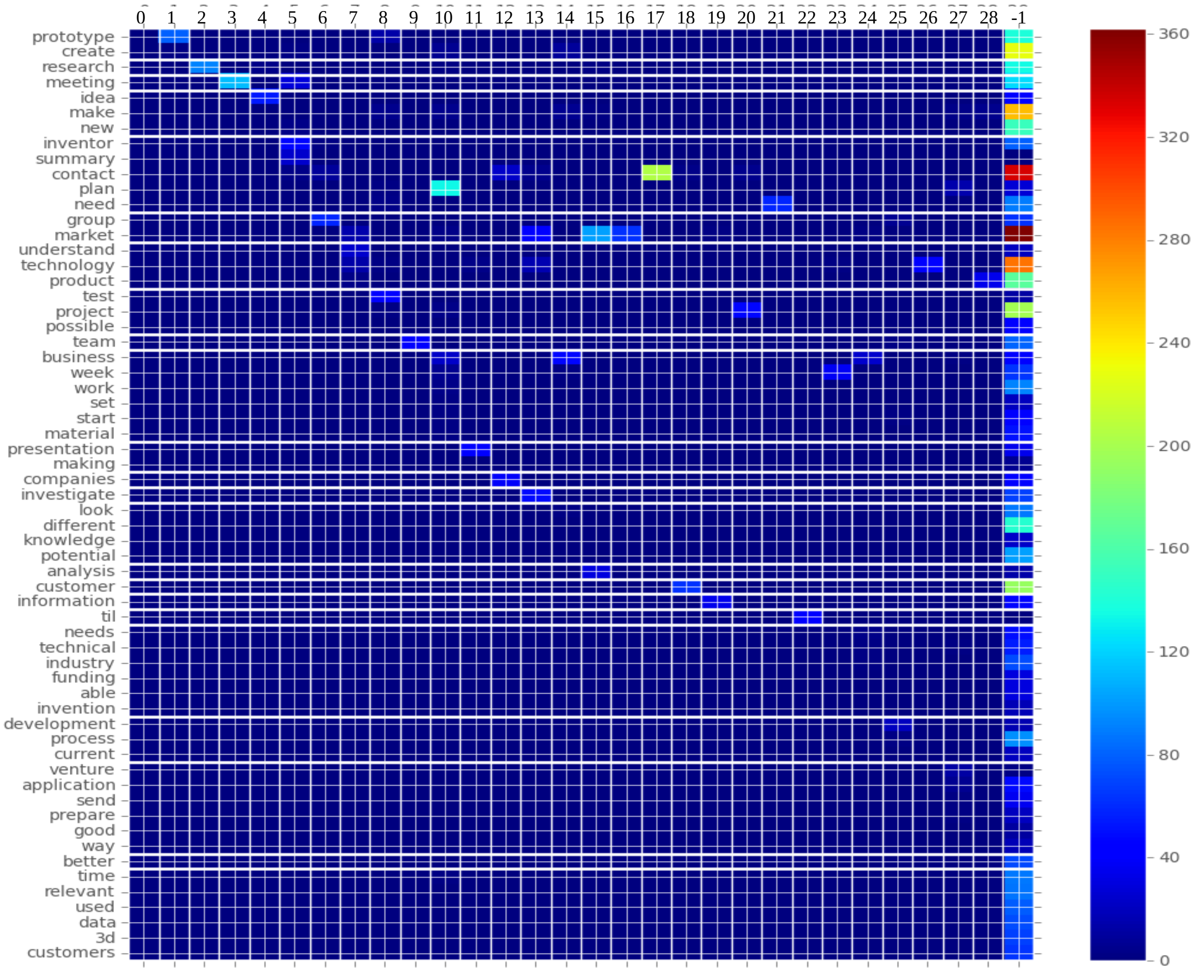


Figure 79: Result of sentences clustering using DBSCAN on the text data vectorised using the v12 vectoriser. Features are shown on left side, cluster number on the horizontal axis. [own]

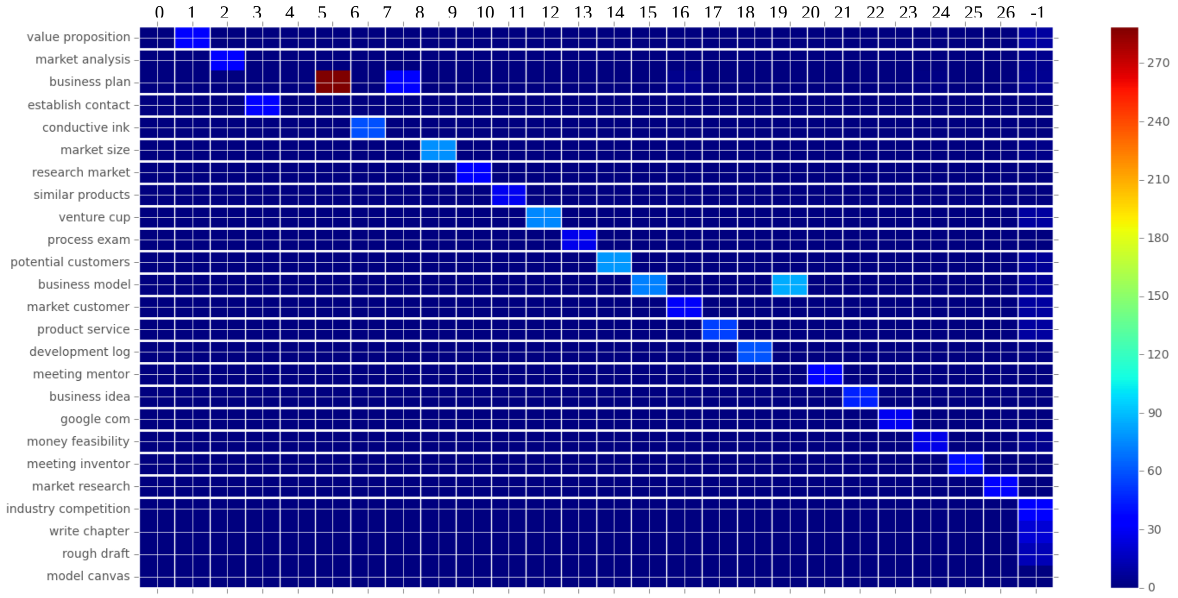


Figure 80: Result of sentences clustering using DBSCAN on the text data vectorised using the v23 vectoriser. Features are shown on left side, cluster number on the horizontal axis. [own]

Table 17 lists the names given to each cluster found based on the *v12 vectorised data*. For this *uni- and bigram* data it was found that a number of clusters where related merely because they used the same word – e.g. *"research"*. If the sentences belonging to the cluster only have one word in common and if this word can be used in many ways, there is a risk that the cluster exhibits poor semantic coherence. If the presence of the word is the only shared feature of the sentences, there the cluster cannot be said to represent a specific topic or feature of the data. Clusters exhibiting these characteristics were dropped (marked by the text "*word*" in parentheses). In certain instances, such as the cluster based on the word *"product"*, the cluster turned out to be meaningful and related to the product's relation to stakeholders, customers, suppliers and the business. For this reason, this cluster was kept.

Another cluster appeared, which contained only Danish sentences. This makes sense as the *stop words* filter mentioned above only works for English words. Frequently appearing Danish words are therefore likely to be prevalent in the very limited Danish parts of the dataset. The prevalence of these Danish *stop words* has caused the cluster to appear. As this is not a justification for the cluster, it was also dropped.

Reading through the cluster sentences, it was clear that certain clusters were closely related – e.g. the sentences in the *business model* and *business model / customer* clusters. To group together related clusters in *super-clusters,* an affinity matrix was created and cluster relations marked by an "X". This matrix is also shown in Table 17 (building on the *v12 vectoriser*). An X is based on a subjective evaluation and indicates that the cluster (row) is related to another cluster (column). This grouping exercise was mainly a practical measure, enabling a visual grouping of the clusters in the visualisations shown later in this study.

The above post-processing tasks were also performed in the data coming from the *bi-* and *-trigram* based *v23 vectoriser.*

The exact grouping was found by exporting the affinity matrix (Table 17) to a network analysis software called Gephi (www.gephi.org). The software redistributes nodes (each representing a cluster), so that they are closer to linked nodes – as defined by the X's in Table 17.

#	Given title	**Dropped**	Noise	Research (word)	Business Model Canvas	Team	Prototyping	Handle information	Presentation	Contacting people	Need (as word)	Meetings	Research / Investigate	Find / engage partners	Technology understanding	Business plan	Summary / Inventor (word)	Project (word)	Understanding Customer	Venture Cup	Group	Market	Testing	(Business) Idea	Development Log	Market size	Danish	Week (word)	Understand (word)	Business Model / Customers	Product (word)	Empty
-1	Noise	X																														
0	Research (word)	X																														
1	Business Model Canvas															X				X				X						X		
2	Team																				X											
3	Prototyping												X		X								X								X	
4	Handle information								X																							
5	Presentation																															
6	Contacting people											X		X																		
7	Need (word)	X																														
8	Meetings													X																		
9	Research / Investigate (word)	X																														
10	Find / engage partners																															
11	Technology understanding																						X								X	
12	Business plan																		X	X		X		X		X				X	X	
13	Summary / Inventor (word)	X																														
14	Project (word)	X																														
15	Understanding Customer																					X		X		X				X	X	
16	Venture Cup																					X		X		X						
17	Group																															
18	Market																									X				X		
19	Testing																														X	
20	(Business) Idea																													X	X	
21	Development Log																															
22	Market size																													X		
23	Danish	X																														
24	Week (word)	X																														
25	Understand (word)	X																														
26	Business Model / Customers																															
27	Product (word)																															
28	Empty	X																														

Table 17: Naming and relating the clusters

Figure 81 and Figure 82, respectively show the resulting cluster plots for *v12* and *v23* data. Two large *super-clusters* form – one more business related (in blue colour) and one more technology related (red colour). Also, three other super-clusters were included – one pertaining to the group and team, one to the interpersonal activities (meetings, engaging, contacting) and one relating to the tool. The dropped clusters are shown as pale, isolated nodes.

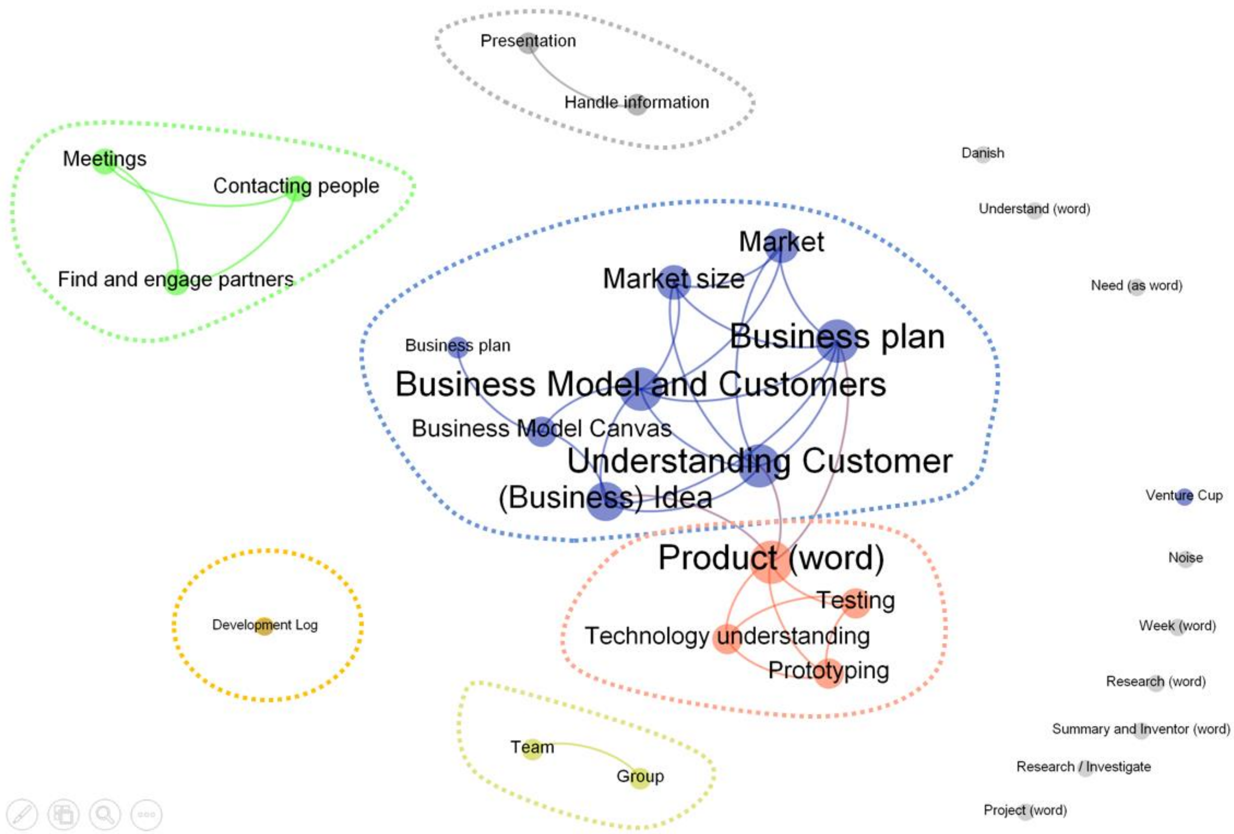


Figure 81: Cluster relations and super-clusters for clusters based on v12 vectoriser (each edge between nodes is equivalent to an "X" in Table 17) [own]

Based on these cluster diagrams, the following super-clusters are proposed as higher level groups for clusters of similar topics – see Table 18.
In interesting feature in Figure 82 is the presence of the *product-service* cluster at the heart of the business modelling *super-cluster*. This feature is very interesting in terms of the overall objective of this thesis (using PSS in the maritime branch) and it will be treated in-depth in chapter 7, section 7.3.1 (page 179).

Another curious feature is the presence of technology-related clusters in the *v12 vectoriser's* clustered data – a feature that is entirely absent in the clustered data for the data *vectorised* using the *v23 vectoriser*. On the other hand, the *v23* data provides a more nuanced picture of the business related parts of the data. In this way the parallel approach to clustering the data has yielded a more holistic account of the phenomenon.

The *super-clusters* will be used as a basis for the visualisations in the coming, *intepretive* and *explanatory* parts of the study.

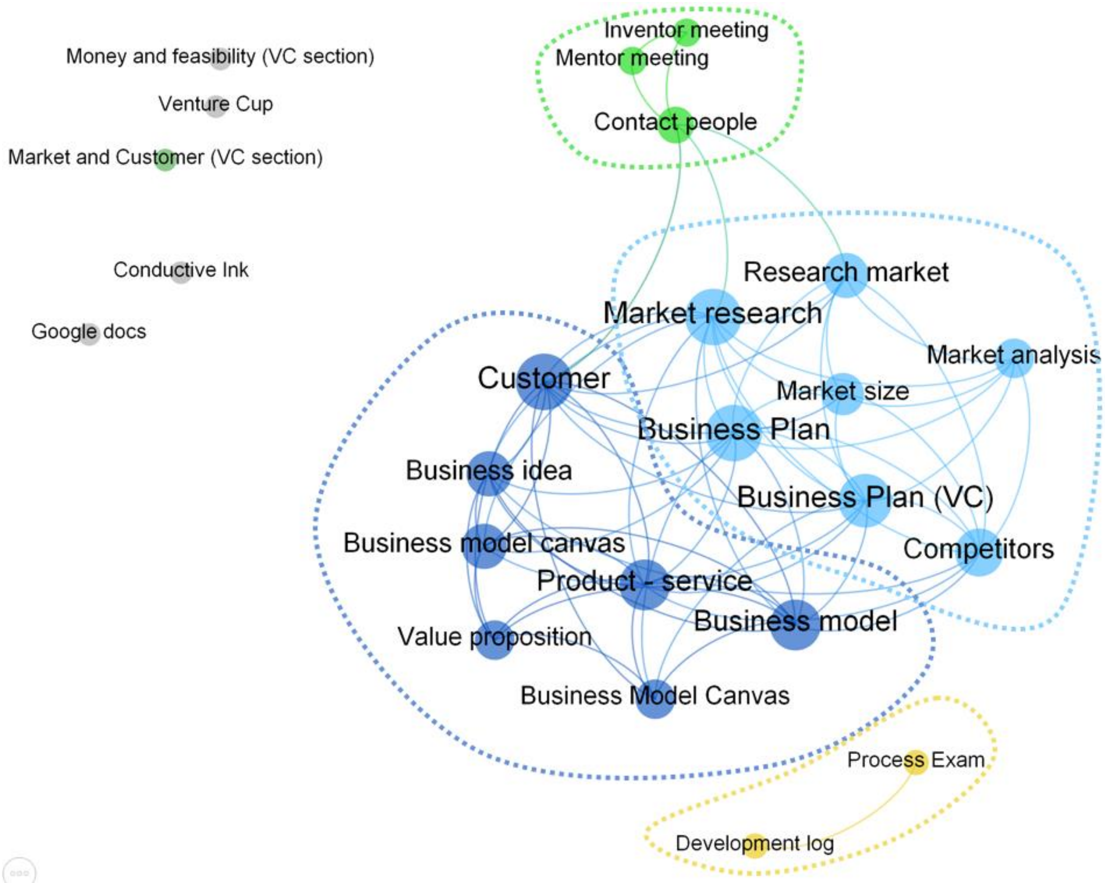


Figure 82: Cluster relations and super-clusters for clusters based on v23 vectoriser. [own]

Super-cluster	*Clusters from v12 clustering*	*Clusters from v23 clustering*
Business modelling	Business Model Canvas Business Model / Customers (Business) Idea Understanding Customer	Business Model Canvas 1 Business Model Canvas 2 Business Model Business Idea Customer Product Service Value Proposition
Business planning	Market Market Size Business Plan	Market analysis Business Plan Market Size Research Market Competitors Market Research
Interactions	Contacting People Meetings Find / engage partners	Contact People Mentor Meeting Inventor Meeting
Practical issues	Development Log [name of tool]	Process Exam Development Log [name of tool]
Tech development	Product (word) Technology Understanding Prototyping Testing	N/A
Handle information	Handle Information Presentation	N/A
Team	Group Team	N/A

Table 18: Mapping of clusters to super-clusters

6.4.3 TAGGING OF DATA

With the named clusters and *super-clusters* in place, the clusters can be used as a basis for tagging the data in the dataset. This tagging enables an understanding of each cluster's role over time in each project and across projects. By using clustered data as a basis for classifying elements, the risk of overlap between classes (tags) is drastically reduced. For this reason, the *precision* for the classifier is above 95% for each cluster – meaning that the classifier's assigned classes will be at least 95% correct (average is 99%). Furthermore, the *recall* parameter indicating the share of entities given a tag out of the total number of entities with that tag is very high, at 86% for the least favourable score (an average of 99%).

6.4.4 A QUANTITATIVE TOP-DOWN ANALYSIS

Using this classifier on the whole dataset produces a graph similar to those used earlier – see Figure 83. However, this time, each colour is related to a *super-cluster* and the two bands of graphs represent the clusters for the *v12* and *v23* data, respectively.

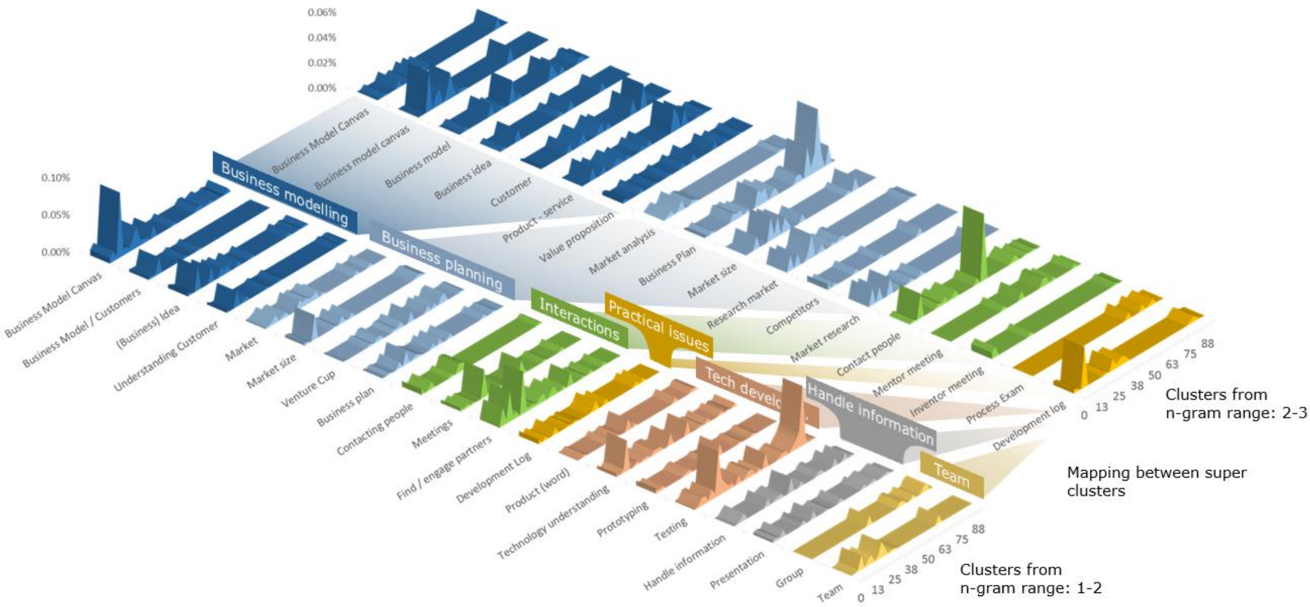


Figure 83: The activity levels for each cluster (grouped by super-cluster) – based on all projects [own]

The figure illustrates a number of interesting and sometimes ambiguous features of the data, which will now be handled in turn. Seeing that the clusters are directly based on the qualitative data in the dataset, the process of deeper inquiry regarding observed features of interest is straightforward, as the underlying sentences for each cluster can be directly inspected.

6.4.4.1 DEALING WITH TECHNOLOGY IN THE EARLY STAGES

As mentioned earlier, the dataset is currently heavily biased by the tech-centric projects running in the technology entrepreneurship course. For this reason, it is no surprise that the cluster relating to *technology understanding* is very active at the early stages of the process. The sentences below are excerpts from the cluster:

***Technology understanding* cluster:**

> *"Understand the technology. Go from knowing nothing, to understanding the technology."*

> *"[name of large company] has been developing a CO2 scrubber technology, find out how it works and how effective it is."*
> *"Understand possibilities and limitations in the technology."*
> *"Work on [name of technology] based drug detector. Is it a viable application idea? What exists on the market? Can it even be done with our [name of technology] technology?"*
> *"Get a practical demonstration of the technology so we can assess its limits and capabilities.*
> *"Write a short technology description about [name of technology]. What is it? Where can it be used? etc."*

The understanding of the technology is evidently a crucial dimension in the early stages of the technology. In several of the sentences listed, not just the technology understanding is mentioned, but also the potential applications, values and limitations of the technology. So one might ask if this is a particular feature of the ventures highly dependent on technology. To provide a contrast, Figure 84 shows the same plot – this time only for the projects where technology is less important.

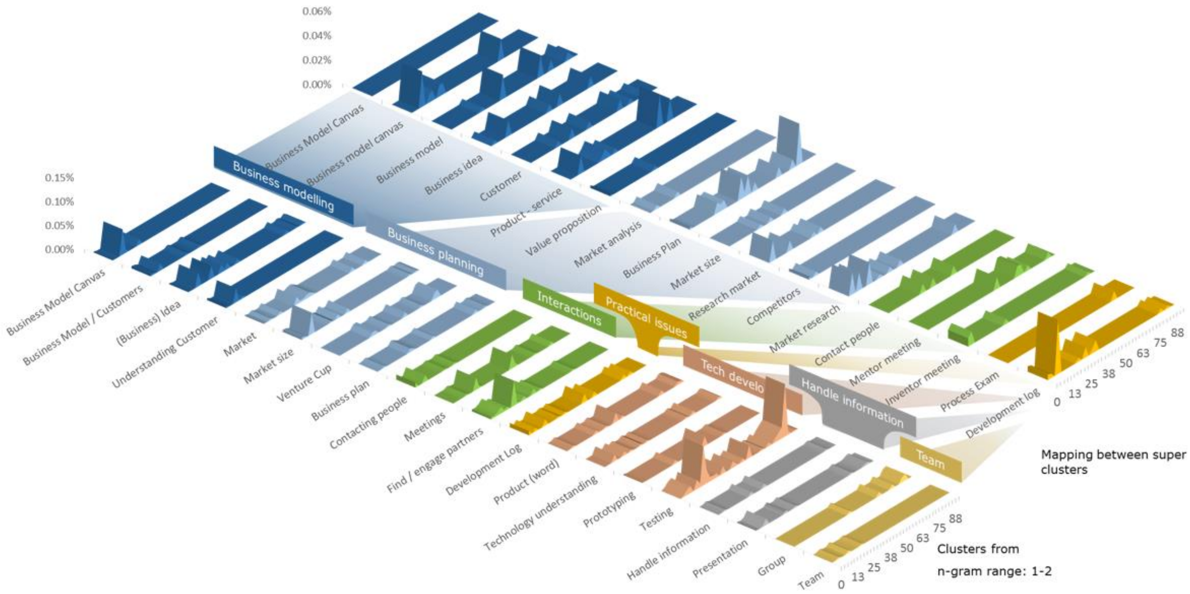


Figure 84: Clusters plotted for projects where technology is less important. [own]

As one would expect, the *technology understanding* cluster is much less active in this subsample. Also, the early peak of activity observed in Figure 83 is absent, indicating that the projects, which are less dependent on technology spend less time on familiarising themselves with technology at the early stages of the project.

Based on these insights it can be stated that the early stage dynamics of a technology-dependent venture should somehow consider technology as a conceptual component. In addition, it can be stated that the technology understanding contributes to the team's understanding of potential solutions.

6.4.4.2 CONCEPTUALISATION OF BUSINESS AND SOLUTION

Maintaining a focus on the very early stages of the process, it is clear that a number of other clusters are active at the same time as the *technology understanding* cluster – including the *business planning-*, *business modelling-*, *team* and *interactions super-clusters.*

The *business planning super-cluster* and its various clusters dealing with market insights are particularly active in the early stages – with the exception of the *business plan* cluster, which is very much related to the act of writing a business plan. Below, some excerpts from the sentences contained in the clusters are provided.

***Market Research / Research Market* clusters:**

> *"Uncovering possibilities on the market."*
>
> *"Get statistical data from etc. Danish statistics that is relevant for market research."*
> *"Research market segment: Pharmacies"*
>
> *"Knowledge from field trips and market research structured into problems and prioritized…"*

***Competitors* cluster:**

> *"Initial competitor analysis. Investigate similar products"*
>
> *"Investigate similar products, which are related to [attribute of technology]."*
>
> *"[name of competitor] have similar products, and is a competitor, they could be interested in buying the patent."*

***Market analysis* cluster:**

> *"Market analysis of the top ideas for uses. We need to figure out* how big the market *is for our top ideas"*
>
> *"Market Analysis of energy demand and forecast. Estimate the future trends in the energy market, possibly with some data."*

The contents of the clusters offer evidence for business ideas being formed based on *opportunity recognition* (a Schumpeterian perspective [J. A. J. Schumpeter 1951]) as well as on *opportunity creation* [Bruyat & Julien 2001; Sarasvathy 2008]. There are several instances of ideation activities based on market insight, but the opposite is also true – market analysis being used as a step subsequent to ideation. In short, there is no clear tendency towards market analysis pre-empting idea creation or vice-versa.

The activity in the *interaction super-cluster* – especially in the *find / engage partners cluster* – provides an understanding of the way in which the information necessary for market understanding and ideation is collected. Relevant partners are identified and often also engaged.

Find / engage partners cluster:

> *"Original Equipment Manufacturer, we should find out the customer segments of [technology] and make appointment with them"*
>
> *"Formulate specs and mail to relevant companies within this area, see [Google Docs] for links to companies and specs."*

The presence of this cluster in the early stages speaks toward a focus on both understanding the stakeholders, but also engaging with the stakeholders while in the process of ideating. The *business modelling super-cluster* is also very active in the early stages of the process. The *(Business) Idea* cluster clearly underlines the general focus on ideation in these early stages:

***(Business) Idea* cluster:**

> *"We need a business idea"*
>
> *"We have a lot of idea now. We really need to find out niche. What is the hole in the market? What dots to connect?"*
>
> *"Let us all put our ideas on the table and discuss them."*
>
> *"Find 5 ideas each"*

The coincident peak in activity for the *business model / business model canvas* clusters is based on the following exemplary entries:

***Business Model Canvas* related clusters:**

> *"We need to sketch out the first version of the BMC, such that we can illuminate which areas that needs our attention"*
>
> *"The Business Model Canvas. Must create model for [name of technology].*
> *"Business model canvas. Make 8 different business canvas models"*
>
> *"Create BMC with new knowledge. Fill in Business Model Canvas with the new knowledge gained from the meeting with [name of inventor]."*
>
> *"We must generate the first version of the business model canvas."*
>
> *"Rough Business Model Canvas. Creation of the first version of the business model canvas"*
>
> *"Business model on how to commercialize the invention"*

From this, it is clear that the business model canvas is used very much as a to-do list, enabling the team to remember important components of the business idea they are developing. Also, the sentences indicate, that the canvas is filled out in order to provide a tentative business model, which will be adjusted as more knowledge is gained.

Finally, it should be noted that the *development log* (which is the current name of the research tool developed in chapter 6) *cluster* is also very active at the early stages. This has to do with the fact that the teams were initially unfamiliar with the tool. This means that the teams have spent time getting to know the tool early on, resulting in the cluster as well as a peak in the early stages. As this cluster is not seen as a part of the phenomenon itself, it is not included in the coming sections.

6.4.5 A CONCEPTUAL FRAMEWORK FOR THE EARLY STAGES OF TECHNOLOGY VENTURE PROCESSES

The *discretisation*, *vectorisation*, *clustering*, *visualisation* and *explanation* of the qualitative data in the dataset have enabled the creation of a *conceptual framework* for the initial stages of idea development in technology ventures. As stated earlier,

> *"A conceptual framework explains, either graphically or in narrative form, the main things to be studied – the key factors, constructs and variables – and the presumed relationships among them. Frameworks can be rudimentary or elaborate, theory driven or commonsensical, descriptive or causal."* [Miles 1994]:

Below, the previously discussed clusters and their relations are explained, in terms of this new *conceptual framework* – see Figure 85. The conceptual components are abduced directly from the super-clusters. The underlying clusters are shown as lighter circles within each component.

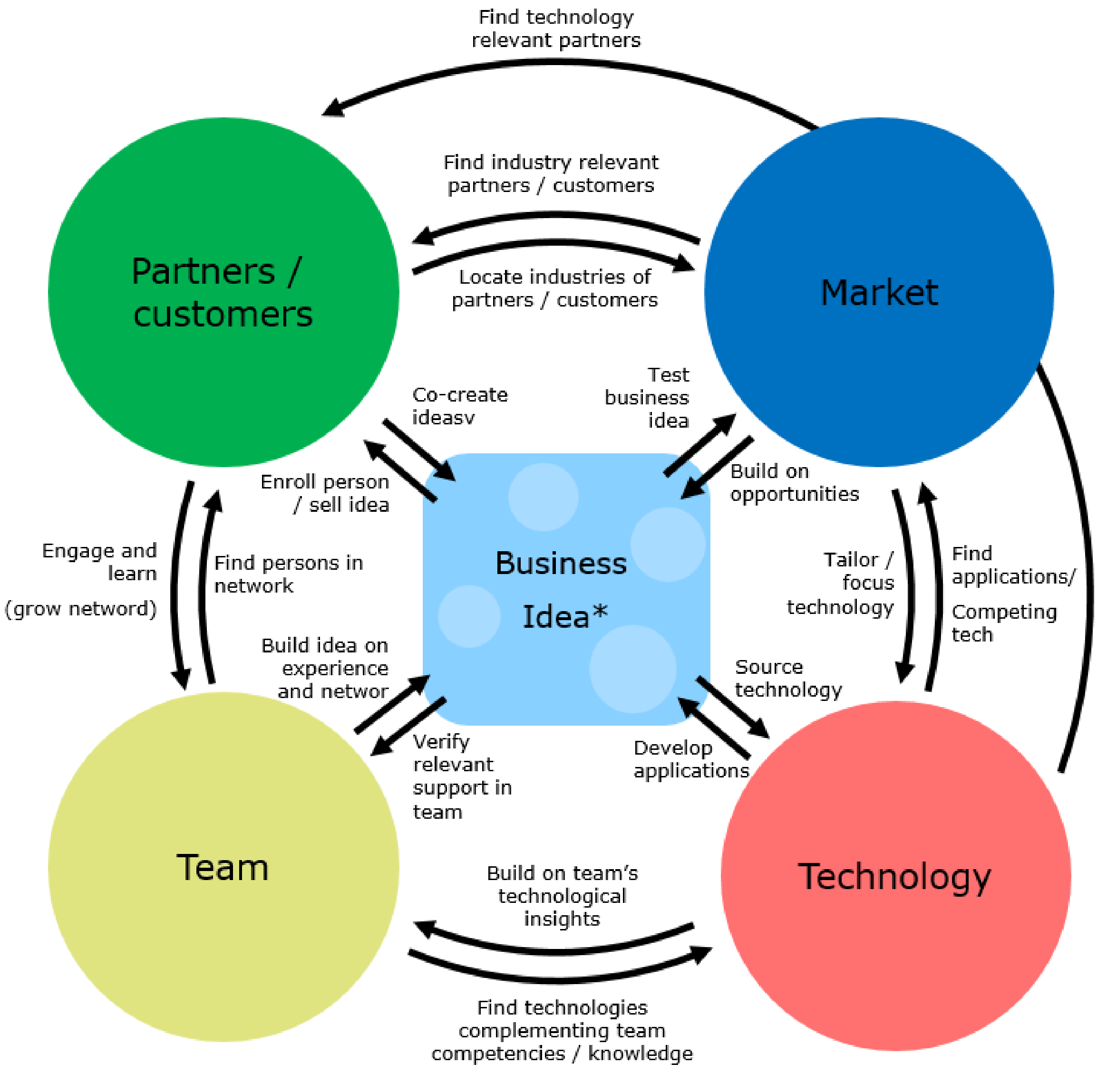


Figure 85: A conceptual framework for early stage development of business ideas in technology ventures. [own]

The relations have been established by the inspection of the underlying descriptions in each cluster and the causal links described therein. As the dataset used for building the *conceptual framework* contains mostly process-oriented data, the emerging framework is also described in terms of the *actions* performed by the team as they build their idea.

The *conceptual framework* is not meant to be normative in nature – it merely provides an understanding of the conceptual components and relations present in the very early stages of idea generation in the observed technology ventures. The arrow labels all refer to actions and to some extent the purpose of that action. They do not offer solutions as to how these actions should be performed.

As stated earlier, clear differences were found between the early stages of technology-dependent ventures and those not reliant on technology. The early stages of ventures not relying on technology can be described in a filtered *conceptual framework*, where the technology component has been faded out (Figure 86). This is not to state that technological dimensions will not be relevant in understanding the processes in these ventures – rather it is a statement of the technology not being a significant influencing factor in forming the initial business idea.

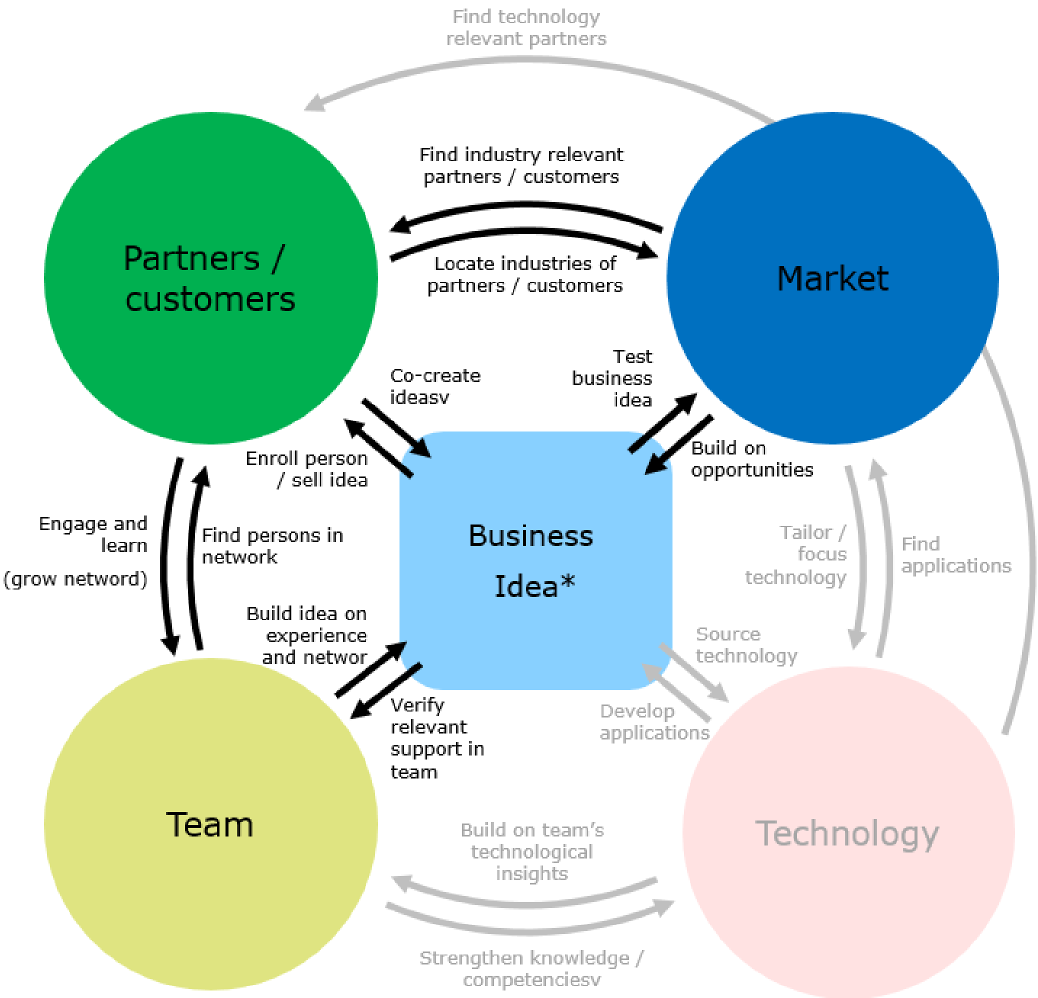


Figure 86: Framework modified for entrepreneurship processes not dependent on technology. [own]

6.4.6 RELATION TO OTHER THEORETICAL DESCRIPTIONS

Up until this point, the study has focused on the empirically driven abduction of a *conceptual framework* and little reference has been made to extant frameworks and theories for the same or similar phenomena. This is partly because of the fact that the area of entrepreneurship process research suffers from lack of empirical foundations [Neergaard & Ulhøi 2007; Moroz & Hindle 2012] – an ailment, which the present study has attempted to address. However, in this last part of the study, the relations and differences between the new *framework* and literary references are discussed.

The framework in Figure 85 is reminiscent of many of the conceptual components found in Gartner's process framework [Gartner 1985]. One clear difference is that in the new framework, the process dimension is not in itself a conceptual component. Rather, actions/processes are what links the conceptual components of the model. Also, the *organisation* – a central component - is not explicitly stated in the new framework. However, one could argue that this is due to the fact that the new framework attempts to describe the very early stages of the process, where the *organisation* has yet to emerge.

In Bruyat's perspective [Bruyat & Julien 2001], the dialogue between new venture creation (*NVC*) and Individual (*"I"*) is at the core of the development process. The framework presented above retains the *constructivist* perspective, but goes one step further to explain how the process relates to the different components of the *I⇔NVC* dialogue. Also, it is not directly obvious how the newly introduced conceptual components should be mapped to Bruyat's framework or if this is at all a sensible thing to do. To still venture an attempt, the "I" can be seen as a decent representation of the *Team, Technology* and *Partners / Customers* components and the *NVC* as the *Business Idea* and *Market.*

One major difference between both existing frameworks mentioned and the newly developed framework is the complete absence of technological dimensions in the former. Park's [Park 2005b] model determining the intersection between the *Knowledge and Experience of the firm*, *The Entrepreneur* and the *Technology* as the origin of innovation is an example of a model that manages to include the technological dimension, but fails to capture the role of the market and relations (*partners and customers* in the new framework).

Generally speaking, the new *conceptual framework* covers many of the components of extant frameworks and none of its components can be said to be new, seen in isolation. As such, the framework provides a platform for consolidating the existing frameworks. Importantly, this integrative feature of the new framework is not a consequence of an extensive literature study and deliberate attempt to find common traits for existing frameworks. Rather, the framework is entirely founded on empirical evidence and a new method for abducing abstract concepts and relations from large qualitative datasets.

6.4.6.1 LIMITATIONS OF STUDY 3

Throughout the description of the study, interpretive steps have been made explicit as has decisions on e.g. which clusters to proceed with and how clusters are grouped in *super-clusters.* The use of various software tools has also been made clear and explained, in order to enable peers to replicate and criticise the execution of the study design. Below, some of the limitations of the study are discussed in more detail.

First and foremost, the *sample bias* [Robson 2011] issue of the study needs to be addressed. When discussing the sample in *Study 1* earlier in this chapter it was pointed out that projects related to the technology entrepreneurship course would bias the sample. This is confirmed by the fact that the final *process exam* and the course support tool (the *development log*) appear as features in the data. The same bias issue occurs for the most data-intensive project in the database, which deals with *conductive ink* – a term appearing as a core feature of a cluster. Having stated this, it should also be pointed out that the clusters appearing in the current dataset are rarely project-specific compared to clustering attempts made on the earlier versions of the database.

As discussed in study 1, this bias does not invalidate the sample as a proper representative of *entrepreneuship* as a phenomenon – it merely cautions proper characterisation of the sample boundary conditions to determine which variety of entrepreneurship is being studied. For an extensive introduction to the characteristics of the sample, revisit study 1, which deals with the same data.

As the variance of boundary conditions for projects within the sample is well-described, the *internal generalisability* is thought to be quite robust. However, when speculating in *external generalisability,* one should be sure that necessary boundary conditions are known for the external cases and compared to the present sample before proceeding to any conclusions.

Although atheoretical in nature, the present study does assume that a number of interpretive steps performed using computer models are valid (*interpretive validity*) – these include the use of *vectoriser models*, *Euclidian distances* as a proper measure for gauging semantic similarity, and the use of clustering algorithms such as DBSCAN. Although the use of these approaches can be discussed, they are clearly stated and replicable. In all aspects of these interpretive steps, an attempt has been made to follow best practice for each model.

Pertaining to the robustness of the results, extensive attempts have been made at adjusting the parameters of the *vectorisers* and *clustering algorithm* (DBSCAN) and evaluate the effects of the outputs. The consistency of clusters and nuances captured are very much dependent on the amount of data in the dataset and the model parameters. The parameters presented earlier yielded the most meaningful results, but as the dataset grows, they should be reevaluated in order to ebable the identification of more subtle clusters on the data.

6.5 RELEVANCE TO MARITIME TECHNOLOGY VENTURING

In section 6.2.1.5 (page 130) a comparison was made between student-based projects and projects in maritime ventures (and other “real” projects) were discussed. It was shown that the types of projects presented could all be seen as entrepreneurship and that the characteristics of student projects overlapped with maritime ventures in some areas and diverged in others. In the third study, the empirical data has been used for building a *conceptual framework*, the objective of which is to strengthen the understanding of the entrepreneurship process phenomenon. This understanding is necessary if support for the process is to be developed.

In this section, the ability of the new *conceptual framework* to provide a good descriptive account and understanding of processes in maritime ventures is verified. This is done by applying the framework to an instance of maritime technology venturing: The SILP technology project described in chapter 3 (section 3.4.2, page 43).

6.5.1 APPLYING THE CONCEPTUAL FRAMEWORK TO THE CASE OF THE SILP TECHNOLOGY PROJECT

To verify the relevance of the *conceptual framework* developed in study 3, the explanatory power of the model can be tested on a concrete, maritime case. In chapter 3, the entrepreneurial venture based on the SILP technology was introduced. If the *conceptual framework* is indeed a good depiction of such early stage entrepreneurial processes dealing with advanced technology, it should provide a meaningful basis for describing and understanding the SILP technology project. Based on the diary notes from the two entrepreneurs working on the project (see section 3.4.2, page 43), different stages of the project are now identified and subsequently described in terms of the conceptual framework.

6.5.1.1 GAINING AN UNDERSTANDING AND MAPPING THE STAKEHOLDERS

At the initiation of the project, the two entrepreneurs are given the task of commercialising a new, patented technology for removing NOx from flue gas. The technology, which is based on a recently discovered type of liquid called an "*ionic liquid*" can potentially solve the task of removing NOx without the use of harmful chemistry. This is interesting, as legislation on NOx emissions is being planned in the International Maritime Organisation (IMO).

The two entrepreneurs, who are experienced within the mechanical engineering field, have no experience in within chemistry and the maritime branch. To address this shortcoming, the first 3 weeks of the project are spent on mapping relevant partners and stakeholders with a knowledge of the technology and market. Also, web searches and other materials are used to gain an idea of the potential market.

> *"Started mapping network around NOx emission and the different markets"*

> *"Get to know competitive technologies and how they are installed and function"*

After an initial meeting with the inventors of the technology, the team attempts to formulate an initial business model, but quickly realises that this is impossible with the current level (as indicated with a red X's in Figure 87).

> *"Difficult to fill in the business model canvas so early in the process due to the lack of knowledge about the existing technology and the shareholders on the market"*

More worryingly, the entrepreneurs, looking for applications of the technology in the market, quickly realise that the impending rules were not yet ratified and that disagreements have postponed them until 2021 (at the earliest). Also, if the legislation is passed as that point, it will only apply to new-builds.

> *"A more strict NOx legislation set by the IMO will probably be postponed until 2021 due to the lack of technology options"*

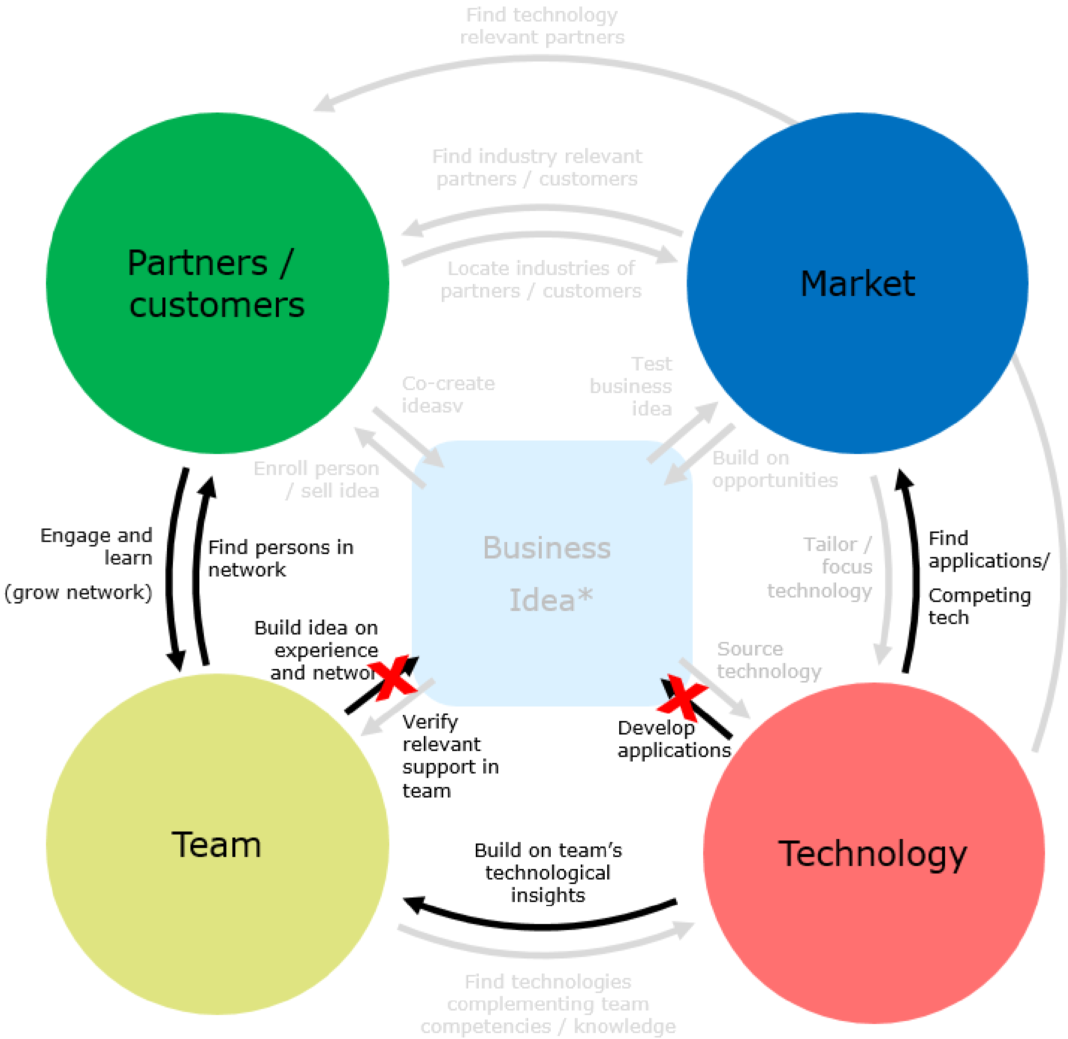


Figure 87: Activities in the early weeks (1-3) of the project. [own]

In this initial period of the project's development, the entrepreneurs work hard to amass knowledge on the market and technology. Unlike Sarasvathy's notion of successful entrepreneurs starting with the questions "*Who am I?", "What do I know?"* and *"Whom do I know?"* [Sarasvathy 2008], these (experienced) entrepreneurs quickly realise that they do not have the necessary knowledge and network to build a business with themselves as starting point. Instead, they adopt what in Sarasvathy's perspective is called a *predictive strategy*. The lack of necessary insights makes it all the more obvious to the entrepreneurs that success depends on their ability to engage relevant stakeholders and build an understanding of the market based on these. This is very reminiscent of Sarasvathy's *patchwork quilt principle* (see section 3.2.3.2).

The idea of the *patchwork quilt* is represented by the relations between the *team* and *partners / customers* components of the *conceptual framework.* In the framework however, *technology* and an understanding hereof is an equally crucial component – in tune with Park's model in Figure 17 (page 48). Without the necessary knowledge and/or relations, it is not possible to create coherent business ideas as exemplified in the SILP technology case.

6.5.1.2 CHANGE OF STRATEGY IN ENGAGING PARTNERS, MAPPING COMPETITORS AND NEW TECHNICAL INSIGHTS

In week 4-6, the entrepreneurs realise a need for re-evaluating the way in which stakeholders are contacted and engaged. Up until this point, the starting point for conversations has been that they are entrepreneurs with a new technology. However, due to patent issues, the team has not been able to share the details of the technology.

> *"It seems like everybody wants a piece of the cake when telling them that we are working on developing a new product/technology that reduces NOx levels according to Tier3 requirements.*
>
> *A shift in focus/approach strategy could be necessary in order for us to get the ball rolling and get the information we need. If companies look at us being students trying to map the area of NOx emission rather than a key to new technology we should have more success getting people to speak freely about the challenges within the industry."*

Using this new strategy, the team manages to arrange meetings with a shipowner and a branch organisation. When meeting with the shipowner, the team gains valuable insights about the technical requirements for any solution to be installed on a ship. They also realise that to succeed in the market, they will have to leverage the credibility and global presence of a shipowner or another company in the branch.

> *"We realized the importance of collaboration with companies in order to open up and create awareness for new innovative technologies. The Maritime industry is a very conservative industry unwilling to invest in new technologies before it is absolutely necessary. A "first mover company" is therefore necessary in order to get the technology to market."*

In the same period, the team realises a need for mapping the existing solutions in the market and comparing them to the SILP technology.

> *"We realised that the overall tasks for the day was to create a technology overview and brief description of existing technologies. This was made to recap how the* [other name for SILP technology] *process is done today and where the existing technologies are implemented. This will also provide information on competitive technologies in regard to BMC and measures that has to be taken into account."*

This comparison task and other tasks, which depend on technology-understanding are made exceedingly difficult by the fact that the team cannot get in contact with the inventors of the technology. They are pushing forward without a proper understanding of the SILP technology, which is a major point of frustration.

> "[University department of inventors] *has still not replied to our mails, and new measures must be initiated to get the information we need"*

Also, the team is generally challenged by the fact that they know little about the field in which their technology is to be used.

> *"Knowing a lot of business- and product development tools makes*

> *tool use straightforward, but the lack of knowledge requires a lot of reading and researching in a field far from what we are used to work with."*

In the conceptual framework (Figure 88), the difficulties faced by the team in gaining the necessary technological understanding are again indicated by a red X. At this stage, the team has yet to explicitly mention any work on potential business ideas and products built on the technology.

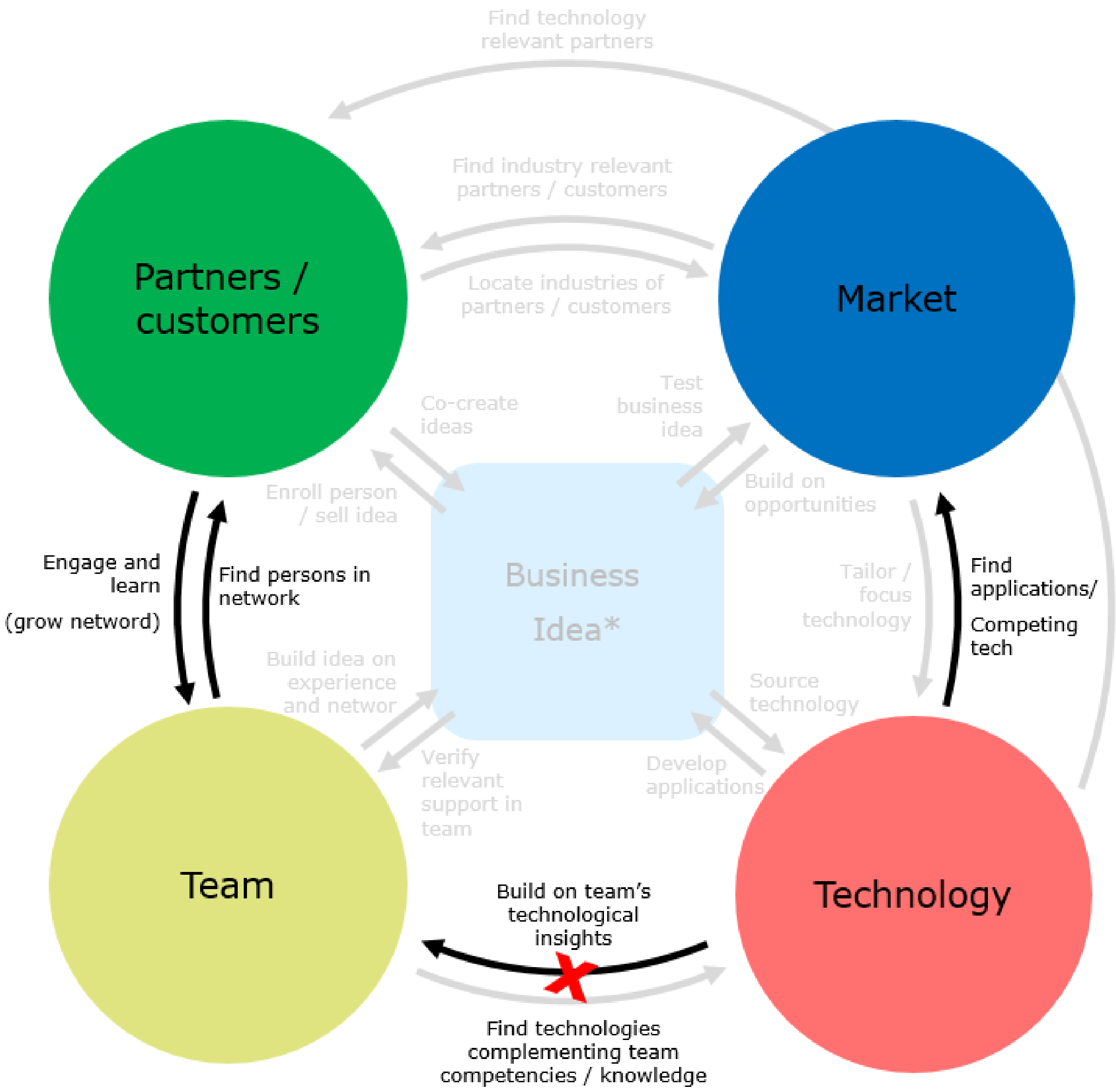


Figure 88: Activities in week 4-7 of the project. [own]

This period yields a new perspective on the *conceptual framework*. As already stated, the team has to engage with people and organisations to gain the necessary knowledge for building solutions. In week 4-7 the team realises that, the role of the network is crucial to the success of their business and that well-thought-out strategies are needed for enrolling stakeholders and for ensuring that the right type of relationship is established. This is again reminiscent of Sarasvathy's *patchwork quilt principle*, but with the added dimension of strategies for stakeholder enrolment (such as *interessment* [Akrich et al. 2002]). The notion of finding and engaging stakeholders is a part of the *conceptual framework*, but there are no explicit components dealing with enrolment strategy. This could perhaps be a sensible addition to future versions of the framework.

6.5.1.3 A NEW UNDERSTANDING OF TECHNOLOGICAL VALUE AND POTENTIAL CUSTOMER SEGMENTS

In the beginning of the period from week 7-9, the team finally manages to arrange a meeting with the inventors. Unfortunately, the inventors do not show up, but the team meets with colleagues of the inventors, who are also associated with the project. This meeting fails to give the two entrepreneurs the technological insights they are hoping for. Furthermore, the meeting reveals that the technology patent has in fact been filed and that there is no reason for withholding information regarding the technology when engaging with stakeholders.

> *"Inventors are clearly not communicating together"*
> *"They are not taking us seriously"*

Luckily, the team is more successful in their engagements with other stakeholders. In the same period several meetings are held with various stakeholders.

> *"The day started out with a meeting at* [large engine manufacturer] *with* [name of employee]. [name of employee] *is emission expert at* [large engine manufacturer]. *Important aspects of the meeting was seeing a ship engine and get specific data on emission components. Emission data is very unique to each engine produced and no new build engines coming from* [large engine manufacturer] *are standard."*

Later in the same week, the team finally gets a presentation of the current status of the technology from the inventors. This improves their understanding of the technology, but also makes it clear that the technology has been developed in isolation, with no connections to industry. Going forward, the team needs to handle the role of translating industry needs into relevant specifications for the technology developers (inventors).

> *"The* [inventors] *have no real collaboration with the industry and are working on their own ideas instead of working towards the industry demands and requirements."*

In the same period, the team recognises that protecting the environment cannot be the main selling point for the technology, as other technologies provide the same benefit. Rather, the newly obtained technological insight has revealed that the real advantage of the technology is that the drop in overall propulsion efficiency related to other technologies is less severe for the SILP technology. This means a cost saving for the shipowner.

> *"Maybe a retrofit of the* […] *technology would allow engine designers to optimize for* [propulsion efficiency metric] *rather than a trade-off between NOx and* [propulsion efficiency metric]*"*

Also, the team suggests the opportunity of integrating their filter technology in other systems, which are currently being installed to meet other emissions requirements (e.g. SOx).

> *"[Install] The technology in combination with [other technology], which has to be installed anyway due to stricter SOx requirements."* (translated from Danish entry)

In the *conceptual framework* in Figure 89 , the red X has been removed indicating that the team has finally gained the necessary technological knowledge. Also, market insights regarding the technology's competitive advantage over alternatives and inputs from technology partners and other relevant stakeholders has enabled the team to start development of various business ideas. These ideas are formulated using the business model canvas. This creation of business ideas based on the improved market knowledge of the team and the technology is indicated at the centre of Figure 89.

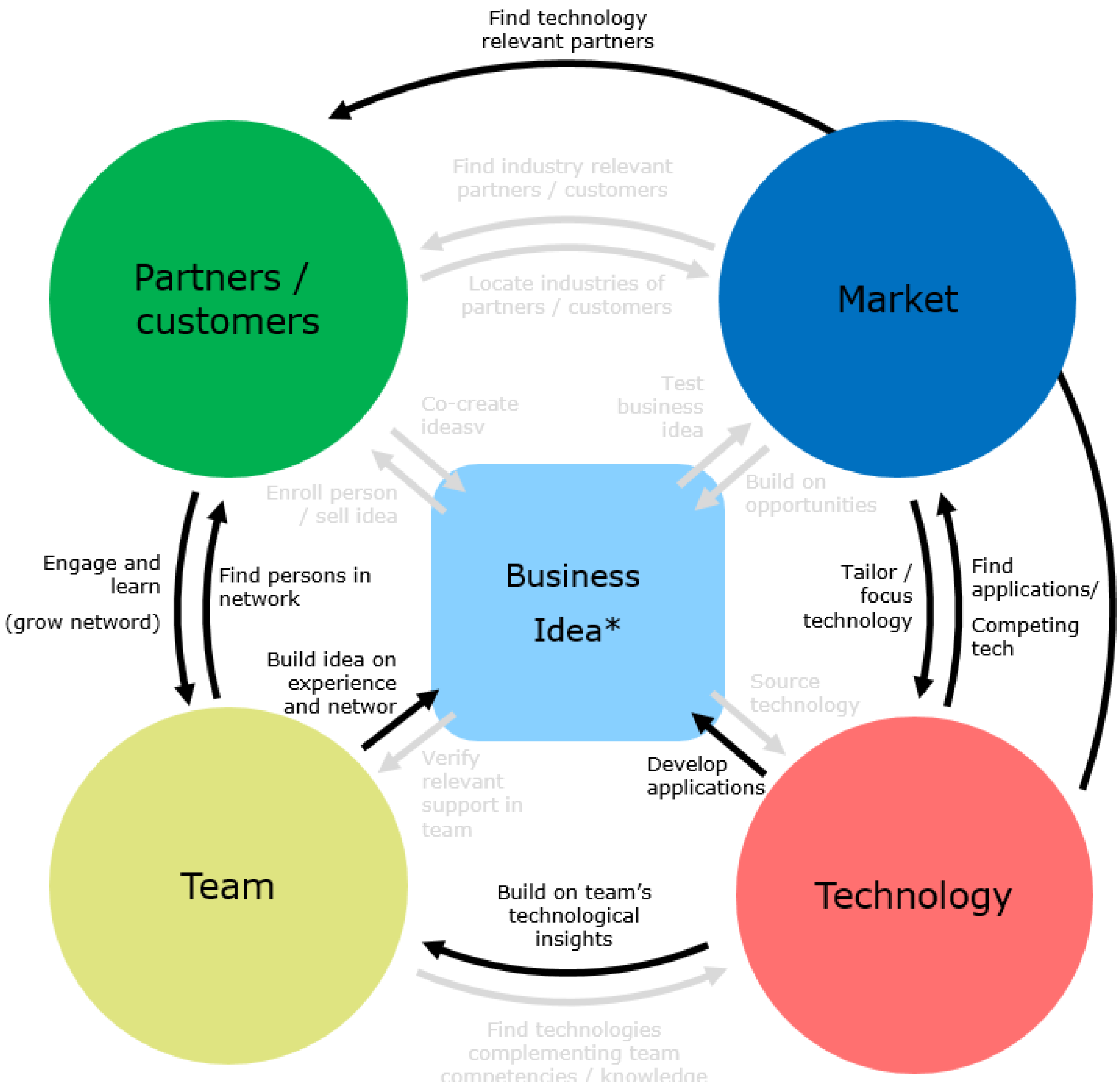


Figure 89: Week 8-10 of the project. [own]

This version of the *conceptual framework* has parallels to Bruyat & Julien's dialogical relation between the "*I"* and the new value creation *"NVC"*, except in this case, the dialogue could be initiated without attaining technological knowledge and. As was argued earlier (section 6.4.6, page 161), the *"I"* needs to be more broadly interpreted if it is to apply to the SILP case – i.e. the *technology* component and *partner* component need to be included. Park's model (section 3.4.3, page 47) explicitly includes these elements (*the entrepreneur, knowledge and experience of the firm and technology*), but does not cover the dialogical (*constructivist*) principle, which becomes important in the next period of the project.

6.5.1.4 TESTING BUSINESS IDEAS WITH POTENTIAL CUSTOMERS

In week 11-15 the team manages to establish meetings with several relevant stakeholders including four shipowners (the customer) operating different types of vessels.

The meetings with these shipowners reveal several insights concerning the viability of the new business ideas.

> *"*[Employee at shipowner] *also provided insight on how our different business model ideas would perform."*

> *"Service systems are difficult as they do not work for all types of vessels and require a huge infrastructure, which is financially difficult for a startup ventures. Collaboration with existing companies such as* [name of two engine manufacturers] *could be a solution as they already have a network of service and maintenance collaborators"*

The meetings also revealed insights concerning what type of vessel and customer to target to gain the most from the technology and business.

> *"Another interesting input gained from this meeting was the fact that an operation time of 50% inside an ECA* [Environmental Control Area] *is necessary for a repayment period of 5 years. Dividing ships according to operation time could be a method for segmentation of potential customers"*

> *"Small container ships (less than 1600 TEU) operates mainly inside ECA as they collect cargo from small harbours for eventually reloading the cargo onto larger ship at main shipping hubs"*

> *"We have become aware of the fact that auxiliary engines also need exhaust gas cleaning and that these systems are much smaller than the systems required for main engines"*

Despite these new insights, the two entrepreneurs are finding it difficult to evaluate, which business model is most attractive as the market size is difficult to calculate.

> *"It has been difficult to develop and target business models towards the most [attractive] market as the actual market size has been unknown until now."*

Meetings with employees in the technical departments of several shipowners and a visit aboard a ferry further improves the team's understanding of the technical and operational requirements for the technology.

> *"This gave us knowledge on more technical aspects such as channel sizes of the existing funnels. Channel size should be minimum 2-3 cm. Information about the challenges on maintenance and requirements for new technology was obtained."*

> *"If a modular filter solution has to work, it must be constructed as a container and placed in reach of the container cranes."*

Despite having gained a substantial amount of knowledge, the team is still very frustrated by their general lack of competencies relevant to the maritime sector and in chemistry.

> *"The technology has therefore been "black boxed" and the concept development has focused on the surrounding system instead"*

> *"As the technology is far from mature, it is impossible to develop a concept in which the technology should operate…"*

These are some of the last reported events from the *technology entrepreneurship* project dealing with the SILP technology. In the last entries in the diary, the team proposes that a partnership is established with an engine manufacturer, which is losing market shares, as the technology could be a differentiating factor for their products.

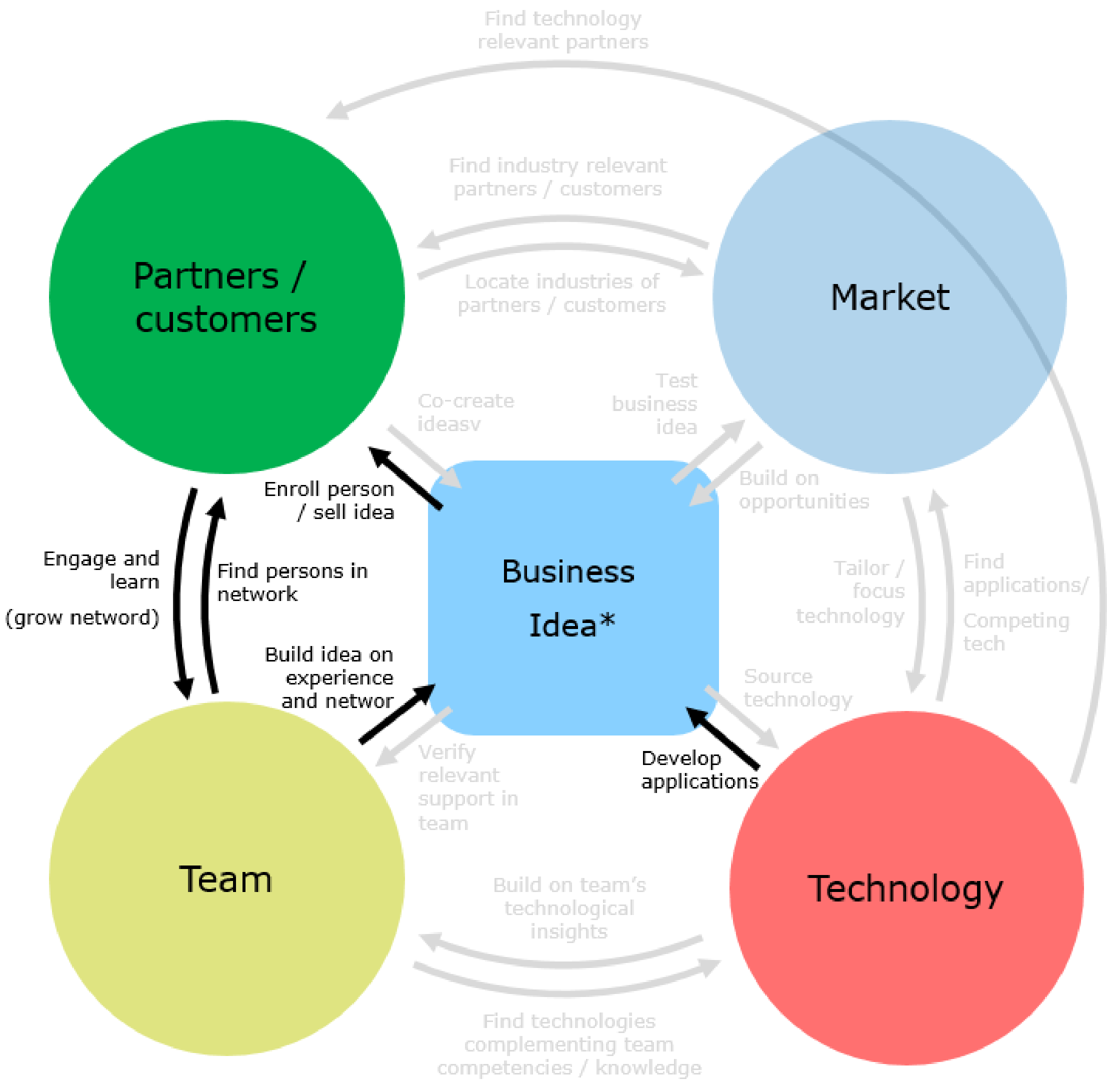


Figure 90: Project activities in week 10-15 [own]

In Figure 90 a version of the conceptual framework is provided, which reflects the activities described above. A critical feature of this figure is the dialogue between the business idea, the customers (shipowners) and the team. This dialogue enables the team to iterate on the initial idea and arrive at a business idea for a specific, commercially attractive segment.

This period of the project (weeks 10-15) clearly underline the importance of the dialogical principle of Bruyat & Julien and the general *constructivist* perspective of entrepreneurship. Instead of striving to attain enough knowledge to build a “perfect” business model and solution, the entrepreneurs engage in intensive dialogue with the customer and other stakeholders, where several contingent solutions are discussed. This approach yields insights on many different areas relating to business model (segments, value proposition etc.), but also to the technology (filter channel diameters, auxiliary engines etc.). These insights from the SILP case underline the fact that *technological* dimensions cannot neglected when describing the emergence of the technology venture and its solution.

6.5.1.5 EVALUATION OF EXPLANATORY POWER OF THE CONCEPTUAL FRAMEWORK

The SILP technology case has been described in terms of the *conceptual framework.* The description provided is simplified, but it manages to capture the main components of the early stages of the SILP technology’s development and commercial exploitation. Most of the framework’s components are used in the process described and the framework has provided a basis for discussing other frameworks for the phenomenon and their shortcomings. In particular, the *conceptual framework* provides a basis for understanding the interplay between technology and the other conceptual components – a feature that existing process frameworks fail to cover.

In the case presented, the framework-based description of the process does not include insights into the short-term cognitive strategies (*micro strategies*) of the entrepreneurs. This is mainly due to the diary notes, which on average were available for every second day of the project.

This does not mean that the *conceptual framework* is incapable of describing these activities of shorter time spans. One should bear in mind the empirical grounding for the framework, as this forms the basis for the conceptual components and relations: The underlying empirical data includes both short- and long-term processes and activity durations down to the 10-second range. This means that the *conceptual framework* should be able to represent processes unfolding over seconds, minutes and hours.

The framework provides a system for grouping and relating various activities in the process, but it does not provide a time perspective. In terms of Moroz & Hindle’s taxonomy for process models (see chapter 3, *Entrepreneurship Process Research*), the *conceptual framework* should be classified as *static framework,* meaning that it does not provide a sequential order for its elements. However, a time dimension can easily be added, by tagging the conceptual components in the data using the approach described in study 2.

6.6 CONCLUSION: A NEW EMPIRICALLY BASED VIEW ON TECHNOLOGY ENTREPRENEURSHIP PROCESSES

In this chapter, the newly developed EPR Methodology has been applied, to gain valuable empirical insights into the phenomenon of entrepreneurship processes and the subset of this phenomenon where the ventures are dependent on technology.

In the first study, the underlying structure of the data captured using the tool was explored and the projects behind the data were discussed, in terms of their general characteristics. The contextual data enabled the isolation and comparison of processes within sub-samples with different characteristics. This provided a basis for exploring the influence of market maturity, as well as technology importance and -maturity on the types of activities found in the processes for each sub sample. Although based on a relatively simple set of pre-defined categories, this study supported theoretical assumptions on entrepreneurship strategy and technology risk mitigation.

In the second study, one of the *archetypical study designs* from the EPR Methodology was followed – the *deductive study design.* In this study, the widely used and acknowledged *effectuation* theory and heuristics [Sarasvathy 2008] were tracked in the data and the central claim that experienced entrepreneurs employ *effectual* strategies to a larger extent than novice entrepreneurs was tested. The study, which was based on advanced natural language processing (NLP) and machine learning approaches, did not find any proof for or against the claim made by Sarasvathy. Rather, the study found that there was no strong correlation between experience (of different types) and prevalence of *effectual strategies.* Despite neither verifying nor falsifying the theory of *effectuation*, the study showed how theoretical notions can be tracked in qualitative data, through the application of modern software algorithms.

In the final study of the chapter, the same advanced software algorithms were used for conducting a variation of a *grounded theory study.* The purpose of the study was to explore the qualitative data in the database, without any preconception of theoretical explanations. To do this, another of the EPR Methodology's *archetypical study designs* were used – the *abductive design.* Central to this study was the use of state-of-the-art clustering algorithms, which were used to identify clusters of semantic similarity in the qualitative data. Having identified, sorted and grouped these clusters, the study proceeded to investigate the very early stages of the entrepreneurial processes captured in the dataset. This deeper investigation enabled the identification of causal relations between the clusters and the eventual forming of a *conceptual framework* for the early processes of emerging business ideas. This entirely empirical approach to theory creation (*abduction*) was found to yield a result exhibiting many of the conceptual components of extant theoretical models in entrepreneurship research, while at the same time integrating technological dimensions, which are largely absent in the current theoretical discussions.

In closing the chapter, the explanatory power of the new *conceptual framework* was tested on a maritime technology entrepreneurship process – the SILP project introduced in chapter 3 (section 3.4.2, page 43) maritime technology ventures. Based on a discussion of the relevance of the conceptual components and –relations for describing and understanding the process documented in the case, it was argued that the *framework* is indeed relevant for describing technology-dependent ventures in maritime suppliers.

Despite adding to the field of entrepreneurship research and the understanding of process and technology in ventures, the chapter has refrained from making normative claims based on the theoretical insights. In chapter 7, the potential for using research and insights from the design and innovation research field in the context of entrepreneurship processes will be investigated.

6.7 REFECTION ON CHAPTER CONCLUSIONS

The *conceptual framework* resulting from the efforts undertaken in this chapter constitutes the only known fully empirically based framework of its kind for understanding technology entrepreneurship processes. However, proceeding to use it as a theoretical platform for future research efforts one should bear in mind a number of shortcomings of the framework. In fact, the use of the term “*conceptual framework*” instead of “*theory*” is deliberate and rooted in the following contentions.

Firstly, the size of the sample on which the framework has been built is substantial, but hardly enough to support a general theory. The deep dive into the characteristics of the sample on page 126 showed the diversity of the sample, but also revealed a number of areas, which were poorly represented in the sample. One example is projects reporting that technology is unimportant. The purpose of the chapter is to understand the process data and (in the case of study 3) build a conceptual understanding, which hitherto has been lacking. With no underlying conceptual or theoretical framework for understanding the sample, *external generalisations* cannot be claimed.

With greater diversity and a larger dataset, more subtle features (clusters) will be discernible from the data. As of now, the *conceptual framework* represents the level of detail, which could be drawn from the present data. In the future, the hope is that the data will reveal a sharper picture with more and more significant features than the ones in the current framework. As an example, the current data has not revealed any concrete insights concerning the cognitive strategies (and differences in these) of the entrepreneurs.

The final limitation is the limited time period, currently represented in the data. The vast majority of the data relates to the first 3-4 months (measured since each project registration in the tool) of the projects’ process. For this reason, there is no guarantee that the conceptual framework is valid for later stages of the process. However, the application of the *conceptual framework* to the SILP technology case did show that the conceptual components can be useful in describing technology venture processes running over longer time periods.

CHAPTER 7:
PSS, ENGINEERING DESIGN AND ENTREPRENEURSHIP

RQ2.3:
How can entrepreneurship research be strengthened to better cater to the needs of technology venture processes?

RQ3.1:
How can PSS and other design and innovation research areas be used for supporting venture- and technology development processes?

As the reader will note, the recent chapters have departed somewhat from initial objective of helping maritime suppliers prosper in an ever-changing market. This departure was necessary, due to the fact that research areas, which were initially thought relevant in helping the technology-dependent maritime suppliers to build new ventures, were found to be inadequate and of little practical relevance. The purpose of the central chapters' methodological excursion was to dive deeper into the challenges that researchers face in understanding technology entrepreneurship processes.

In chapter 6, the research methodological considerations were concluded with the introduction of a new and empirically founded conceptual framework for understanding technology entrepreneurship processes. Also, it was shown that, although empirically founded in student-driven cases, the conceptual framework is capable of explaining key components of the maritime suppliers' technology venture processes.

This chapter builds on the insights gained in chapter 6 and discusses the potential for drawing in theory and strategies from design and innovation research. Specifically, the potential of using Product/Service-Systems (PSS) as a supporting framework for the process is explored.

7.1 CHAPTER RESEARCH DESIGN

As this is a discussions chapter, the main methodological support will be in the form of the literary references introduced in the earlier chapters of the thesis. The empirical results, including the new *conceptual framework* for technology entrepreneurship processes, will be used to provide a new perspective on existing models and theories.

7.2 ENTREPRENEURSHIP AS A DESIGN PROCESS

The *conceptual framework* from chapter 6 provides a model for explaining the components and processes in an entrepreneurial process. As was also argued in chapter 6, the *framework* is more or less compatible with the extant theoretical descriptions of the entrepreneurship process.

In chapter 2, a choice was made to investigate whether *technology venturing* could be a way forward for the maritime suppliers. It was also hypothesised that the area of design and innovation research in general and the area of Product/Service-Systems in particular would be of use in the venture process as the maritime suppliers look to exploit new opportunities by way of advanced technology. In this section, the first part of this hypothesis is discussed – namely the relevance of *engineering design* tools and research.

At the very highest level of abstraction, the process of entrepreneurship is one of emergence. In the constructivist perspectives of several prominent scholars [Gartner 1985; Bruyat & Julien 2001; Garud et al. 2010], the entrepreneur is seen as an agent deliberately organising, arranging and creating the components necessary for capturing value. In extension of this, Sarasvathy [Sarasvathy 2008] departs from the common scholarly references and includes Simon's *Sciences of the artificial* [Simon 1969] as an ontological perspective on venture creation.

In design and innovation research, the focus is on the *designer* – a person *conceptualising*, *embodying* and *detailing* the design [Pahl & Beitz 1996] based on requirements set by use situations, stakeholder needs etc. Historically, the thing created by the designer – the *design object* - has been related to mechanical, electrical and later software technology. As the field has evolved, the notion of the *design object* has broadened to include considerations on the market and production side [Andreasen & Hein 1987] and the complex requirements related to activities throughout the product's lifecycle [O. . Mont 2002; Wise & Baumgartner 1999; McAloone & Andreasen 2002].

The *product dimension* of the *design object* has also been complemented by a *service dimension* and together, these give the designer improved degrees of freedom in addressing specific needs [Tan et al. 2010]. Also, the *designers'* task has grown to include considerations on what is required on organisational and network levels to deliver the intended product/service.

Finally, the *design object* has moved from being deterministic with pre-defined meanings and functions, to an object whose meanings and functions are continuously being re-negotiated in a dialogue with stakeholders, technologies, laws etc. [Akrich et al. 2002; Bijker 1987; Verganti 2008]. From being in a reactive role addressing market and user needs, the *designer* has become an agent of change, creating not just products, but also realities and meaning. This constructivist view is called *design thinking* and is strongly related to Herbert Simon's view of the design process, albeit with a broadened design object.

This juxtaposition of entrepreneurship- and design and innovation research is meant to underline the strong parallels that exist between the fields. Table 19 lists a number of central theoretical concepts in entrepreneurship research along with related concepts in design and innovation research.

Entrepreneurship research components	Related design and innovation research concepts
I ⇔NVC [Bruyat & Julien 2001]	Design thinking [Simon 1969] Domestication [Callon 1986] Actor network theory & material semiotics [Law 2009]
Opportunity [J. A. J. Schumpeter 1951; Shane & Venkataraman 2000]	CAC [Vandermerwe 1993] Conceptualisation [Pahl & Beitz 1996] User driven design [Mont et al. 2006]
Lemonade, bird in hand [Sarasvathy 2008]	Agile development processes [Fowler & Highsmith 2001]
Patchwork quilt [Sarasvathy 2008][Simon 1969]	Actor network theory [Law 2009] SCOT [Bijker 1987] Interessment [Akrich et al. 2002]
Pilot in plane [Sarasvathy 2008]	N/A
Affordable loss [Sarasvathy 2008]	N/A
Types of process models [Moroz & Hindle 2012]	Stage gates models [Cooper 1990] Axiomatic design [Suh 2001] Agile development [Fowler & Highsmith 2001]

Table 19: Similarities between theoretical concepts

Entrepreneurship research has provided little in the form of useful support for entrepreneurial practice. Chapter 3 introduced Bygrave's call for his fellow researchers to *"…read some recent issues of our leading journals and ask yourself what have you learned that is important to your teaching and advising and the practice of entrepreneurship."*

In contrast, design and innovation research has a strong tradition of process research founded in design practice and the methods and tools coming from the area are widely adopted by practitioners – as e.g. stage gate models [Cooper 1990], SCRUM [Moore et al. 2007] and product family based architectures [Harlou 2006].

However, as was discussed in chapter 3, the area of entrepreneurship is not covered to any great extent in design and innovation research. The focus has traditionally been to support established organisations in developing new products and services. Design and innovation researchers have been successful in describing design processes by way of *ethnographic methods*, *documentary analysis* and many of the other research methods described in chapter 4. However, when comparing these methods to the list of requirements for entrepreneurship research tools, it became apparent, that they did not provide a sufficient basis for studying the emergence of technology ventures, which is why a new research tool has been developed (chapter 6).

With the help of this research tool, there should be a basis for exploring the relevance and value of design and innovation research theories and methods, in the context of entrepreneurship processes in general and the processes dealing with advanced technology in particular. In the next section, a concrete area within design and innovation is proposed as a natural starting point for such an exploration – the area of Product/Service-Systems.

7.3 PSS IN ENTREPRENEURSHIP PROCESSES

From the previous section, it is clear that the phenomenon of design processes and that of entrepreneurship processes share traits that justify an exploration of how engineering design tools and research can be used in the entrepreneurial context. This also validates the first part of the hypothesis formulated on page 26 in chapter 2 – that engineering design tools are relevant to entrepreneurship processes. The second part of the same hypothesis stated that in Product/Service-Systems in particular could be of use to the entrepreneur. This section will test the validity of this hypothesis by discussing the potential of using various PSS methods in supporting the processes documented in the previous chapters. The *conceptual framework* for technology entrepreneurship processes will be used as a point of departure.

7.3.1 EMPIRICAL EVIDENCE OF PSS IN DATA

Positive indications of the relevance of PSS were already seen in building the *conceptual framework* (study 3, chapter 6). Here, when using the bi- and trigram *vectoriser* (*v23*), *product service* appeared as a cluster of semantic similarity in the dataset. In other words, considerations on PSS are already apparent in the data. Looking at Figure 83 (page 155), one can see that the cluster shows activity throughout the process. A closer look at the contents of the cluster reveals the nature of these PSS activities:

> *"Get in Contact with EuDA. In order to get in contact with other European dredging companies as well as utilising the experience of EuDA for the product/service-system development."*

> *"Reflection upon different sails strategies. Describe pros and cons for different ways of selling our product; product/service system, selling through retailers etc."*

> *"Business Model Canvas for CO2 service model. BMC for the model where we receive CO2 as a product for the service of cleaning the methane gas."*

> *"Market Position. 1.Identify what the value proportion of the product or service 2.Identify the market position accordingly."*

A large share of the data points relate to a specific section in the final report that the projects related to the course had to write. E.g.:

> *"Report section draft: Product and service. Report section draft: Product and service"*

> *"Write Product & Service section of VC report."*

These sentences clearly relate to an imposed formal framework (the Venture Cup report) and can therefore be seen as having a *reactive effect* on the sample (bias). However, as argued on page 130, the bias created by such formats does not invalidate the sample. In fact, the report format referred to is widely used in general entrepreneurship practice as it pertains to a nationwide (Danish) entrepreneurship competition. Despite these reservations on *reactive effects*, the statements in the database indicate that PSS as a concept is already a component of the entrepreneurial practice seen in the samples.

7.3.2 SPECIFIC PSS CONCEPTS IN RELATION TO ENTREPRENEURSHIP PROCESSES

The idea of using PSS in supporting the holistic processes seen in technology ventures can generally be seen a meaningful as PSS is arguably the area in design and innovation research dealing with the broadest *design object.* A PSS solution typically designed to include elements relating to the network of stakeholders, role definitions and features addressing a multitude of needs related to customer activities. To build a solution of such complexity requires the support of various methods, some of which are developed specifically for PSS and some, which are taken from other areas of practice and research.

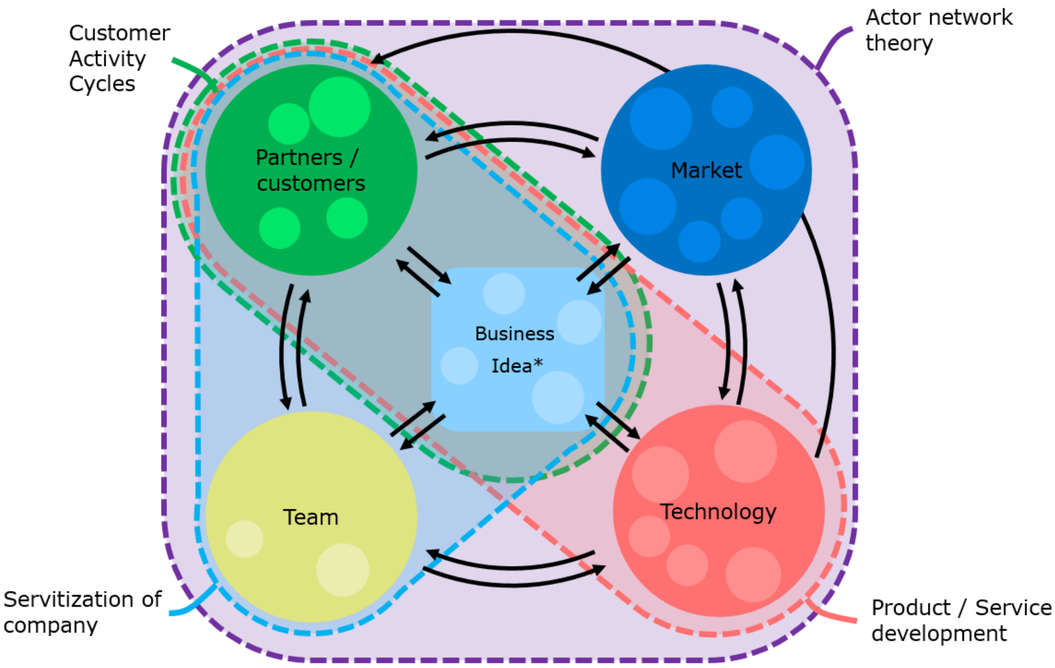


Figure 91: The conceptual framework for early stage technology entrepreneurship processes and its relation to different PSS tools. [own]

A number of core PSS methods (also mentioned in chapter 2, page 20) will now be discussed in relation to the *conceptual framework.* Figure 91 provides an overview of the methods and their relation to the different components of the framework. Although deemed suitable for supporting technology entrepreneurship processes, each method has a number of shortcomings, which will also be touched upon. To provide a concrete reference, the SILP flue gas cleaning technology project will also be used as a basis for reflecting on the relevance of the tool.

7.3.2.1 ACTOR NETWORK THEORY

Actor Network Theory (ANT) [Law 2009] provides a descriptive framework for understanding the relations between actors of various kinds. These actors include persons and organisations, but also non-human *artefacts* like technologies, products, laws etc. Each of these actors will affect the system – human stakeholders through their actions and opinions and non-human stakeholders through their design and characteristics. For any solution to work, the network of stakeholders affecting it must be described.

By instigating *translations* (both in the spatial and semantic sense) in the network, relations, attitudes and characteristics can be changed toward a new order, better in which the proposed solution has a place. In ANT this process of translation also affects the solution itself, meaning that it can and should not be seen as static. Figure 92 shows an example of an actor *network drawn* up for the maritime branch. This network representation served as platform for understanding the current situation (as of 2012) in the maritime branch and it enabled new insights to be made about new business opportunities and their respective relations to various actors.

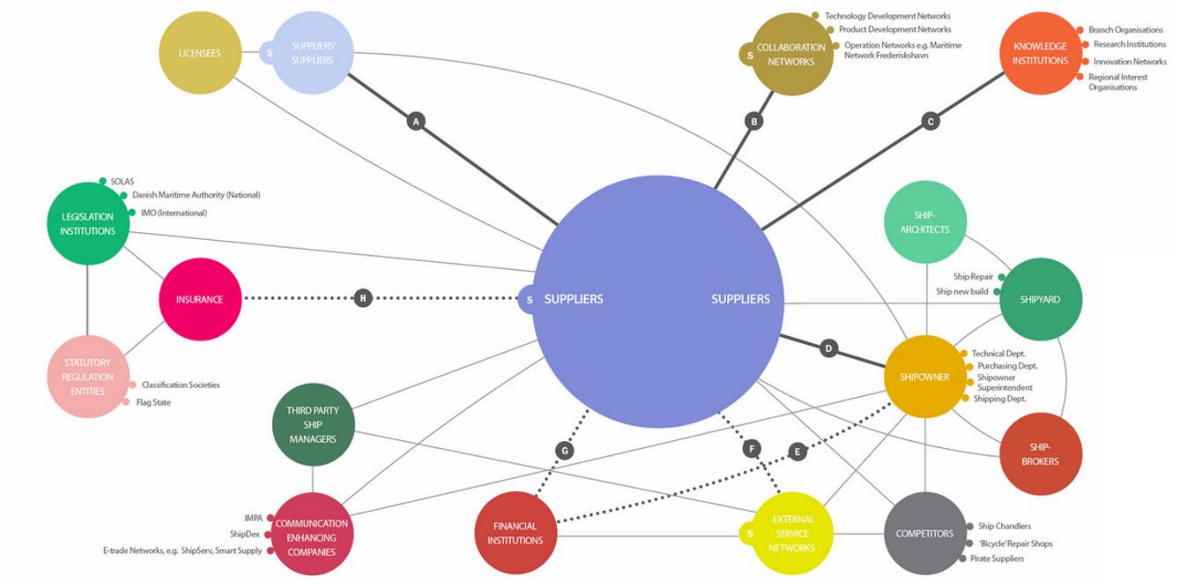


Figure 92: Example of actor network from PROTEUS consortium [Finken et al. 2013]

An important feature of ANT is the concept of a *boundary object* – an artefact (e.g. a document, a machine, a database etc.), which is placed at the boundary between different groups of actors, enabling *translation* of meaning and exchange of information. The type and nature of the interaction is very much defined by the design of the boundary object itself and it can therefore be seen as a vessel for achieving the goals of its designer.

As indicated in Figure 91, the general formulation of ANT enables it to cover the entirety of the *conceptual framework's* components. Being inherently constructivist, ANT also encompasses the ideas set forth by Gartner, Bruyat & Julienne, Shane and other prominent entrepreneurship scholars. The trade-off for this wide applicability is the fact that ANT is less concrete than simpler tools and that the theoretical description of a given context is entirely dependent on the perspective and overview of the person formulating the network. ANT is a tool for understanding, not a normative tool telling the user which relations and meanings to favour.

Another limitation of ANT in its simple form is that it is effective at describing changes in a network where most of the actors are more or less known (e.g. in existing or emerging markets). If the market (the *opportunity*) is something created by the entrepreneur, it is not likely that relevant actors are known a priori – for instance with reference to Sarasvathy's ever evolving *patchwork quilt.* Variations of ANT do however exist, which manage to support the description of new opportunities and markets. One version is the theory of *development arenas* [Jørgensen 2012; Jørgensen et al. 2009], where actors from different (thus far unrelated) *actor worlds* are brought together to compete in the creation of a new network with new meanings.

In the SILP case described in section 6.5.1 (page 163), the two entrepreneurs spent a significant amount of time mapping the stakeholders in the maritime branch and the competing technologies presently being used.

"Started mapping network around NOx emission and the different markets"

> *"Difficult to fill in the business model canvas so early in the process due to the lack of knowledge about the existing technology and the shareholders on the market"*

Furthermore, the team realised that they had to adopt deliberate strategies for positioning themselves in relation to the different stakeholders. This clearly suggests a strong match between the challenges of entrepreneurs and the type of support provided by ANT.

7.3.2.2 CUSTOMER ACTIVITY CYCLES

A crucial dimension of PSS is the move away from the design of products and toward the design of necessary functions to support the activities of the user and customer. This departure from a product-centric designer view leads to the realisation that a function can be achieved in many ways – by either products or services. By thinking in terms of product- and service dimensions, the designer obtains new degrees of freedom, which improve his/her ability to integrate functions of greater quality and breadth. Customer activities and related needs, which were before impossible to support by products alone, become accessible to the supplier, paving the way for improvements in need fulfilment and support for all the customer's activities (the entire life cycle).

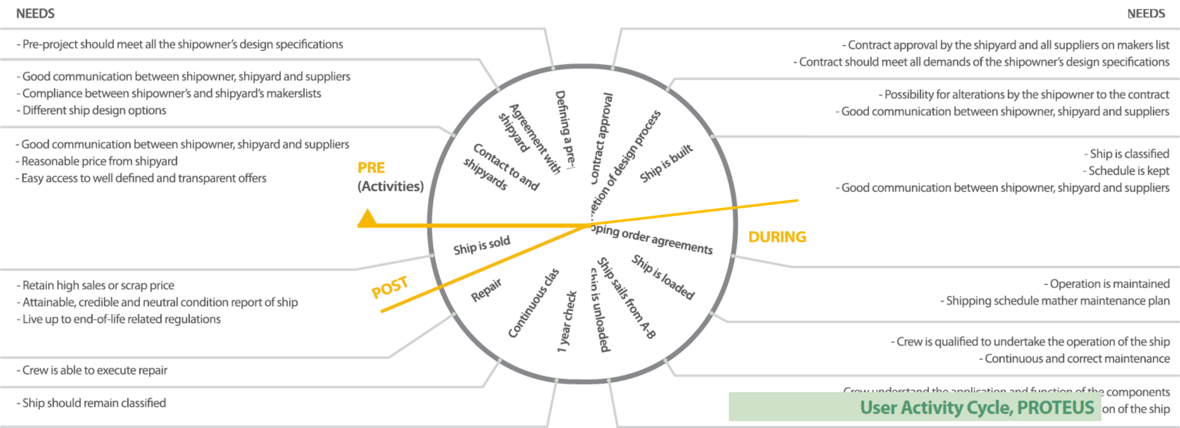


Figure 93: A customer activity cycle for a shipowner and a new vessel formulated by the PROTEUS consortium [Finken et al. 2013]

A prerequisite for the success of any PSS is a strong understanding of the customer's- and/or user's activities. The designer will normally have a focus on specific activities – often in the "use" phase, where a product is used to serve its main purpose. PSS offers a number of normative tools to help broaden the designer's understanding of the customer's activities. One of these tools is the Customer Activity Cycle (CAC) [Vandermerwe 1993], which splits the customer's activities into three overall phases of activities – *pre, during* and *post.* These phases relate to the activities before (*pre*) the customer/user starts using the product, activities related to the main intended use of the product (*during*) and activities occurring after the product has fulfilled its main function and needs to be disposed of or recycled (*post*). Figure 93 shows the CAC for a shipowner procuring, building, operating and selling a ship.

Compared to the theoretical notion of *opportunity* found in entrepreneurship research, the CAC constitutes a very practically oriented and concrete tool, which can be easily adopted by entrepreneurs. Despite being a simple tool, the temporality of customer-/user activities covered by the CAC adds refinement to the accounts provided by popular entrepreneurship tools like the *business model canvas* [Osterwalder et al. 2005].

Although refining the designer's/entrepreneur's understanding of the customer's needs, the CAC still constitutes a simplified account of the actual activities. As with any visual representation, this level of abstraction can be seen as a trade-off between capturing reality as it is and providing an intelligible overview of the phenomenon at hand. One could still argue that the CAC is superior to e.g. the *business model canvas* when it comes to a thorough understanding of the user/customer needs.

Another potential limitation of the CAC is the implied need for the designer to know the activities of the customer/user beforehand or for information about these activities to be obtainable. In the *constructivist* perspective on opportunity creation in entrepreneurship, none of these prerequisites are present. In contrast, the *business model canvas* instructions explicitly state that the canvas is to be first populated with assumptions wherever knowledge is missing. The entrepreneur then proceeds to validate or revise these assumptions.

Unlike the *business model canvas,* the CAC has not been directly designed for use in entrepreneurial ventures and it is not fair to expect the tool to work perfectly in this changed setting. Instead of conceding its incompatibility with cases dealing with constructed opportunities, one could instead consider the CAC in a new role: As a *boundary object* (see previous section) used in communicating/explaining the entrepreneur's understanding of the opportunity. As with any boundary object, the CAC could be used as a dialogue-supporting method for driving *translations* and enrolling actors.

The understanding of the operations of the customer was an important dimension in the SILP project in section 6.5.1. The team clearly considers the activities of the customer in conceptualising solutions:

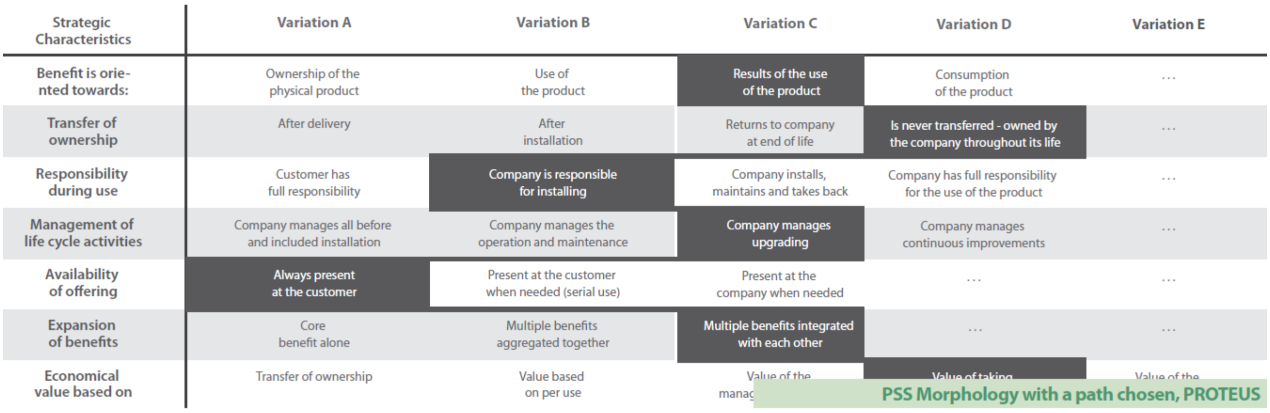
> *"A service system in which SILP modules are changed when the vessel is in harbour do not work for tankers as cranes are rarely available"*

The team does not explicitly state that it uses the CAC, but the consideration of activities in phases other than the "use" phase indicates that they have adopted a similarly broad activity perspective. This clearly speaks to the relevance of the CAC.

7.3.2.3 PSS DEVELOPMENT

As mentioned above, any successful PSS solution is based on a profound understanding of the activities of the customer and/or user. With such an understanding in place, the designer is challenged with conceptualising and realising a solution that delivers the functions necessary for addressing the customer's needs. Such processes of designing solutions to meet customer needs are poorly accounted for in entrepreneurship research. Conversely, such design processes are at the core of engineering design and innovation research. PSS provides several models for translating user activities and needs into PSS solutions.

The insights gained by using the CAC enables the designer to set a list of requirements for the PSS solution. From this point of departure, the designer can proceed to address the requirements by way of products, services or a combination of the two. Again, a number of normative tools exist for assisting the designer in deciding on how the PSS should be configured. The PSS Morphology [Tan & Mcaloone 2006] is an example of a conceptualisation tool, which enables the designer/entrepreneur to explore various archetypical variations on the PSS solution, which have been derived through experience from other PSS solutions. The morphology is shown in Figure 94. The morphology provides a platform for challenging default design choices and making the designer aware of all degrees of freedom in creating the solution. As such, it cannot be used for the detailed design, but rather in establishing the overall configuration of the PSS.



Strategic Characteristics	Variation A	Variation B	Variation C	Variation D	Variation E
Benefit is orie-nted towards:	Ownership of the physical product	Use of the product	Results of the use of the product	Consumption of the product	…
Transfer of ownership	After delivery	After installation	Returns to company at end of life	Is never transferred - owned by the company throughout its life	…
Responsibility during use	Customer has full responsibility	Company is responsible for installing	Company installs, maintains and takes back	Company has full responsibility for the use of the product	…
Management of life cycle activities	Company manages all before and included installation	Company manages the operation and maintenance	Company manages upgrading	Company manages continuous improvements	…
Availability of offering	Always present at the customer	Present at the customer when needed (serial use)	Present at the company when needed	…	…
Expansion of benefits	Core benefit alone	Multiple benefits aggregated together	Multiple benefits integrated with each other	…	…
Economical value based on	Transfer of ownership	Value based on per use	Value of the manag	Value of taking	Value of the

Figure 94: The PSS morphology [Finken et al. 2013]

With an overall idea of the PSS configuration in place, the designer can proceed to develop the products and services necessary for realising the solution. On the product side, a number of tools exist for converting requirements into product features – e.g. the SE-V model by [Eppinger & Ulrich 1995] or the methods proposed by Nigel Cross [Cross 2008]. On the service side, the design problem is mostly related to acquiring the necessary staff to deliver the service, establishing a network [Mougaard, L. Neugebauer, et al. 2013] able to support the necessary activities and formulation of standard operating procedures for delivering directed and consistent services. It has been shown, that organisations, which manage to integrate the (traditionally separate) processes of service- and product development are able to create solutions of superior value to the customer [Isaksson et al. 2009].

Although helpful in broadening the scope of the solutions developed, the PSS morphology, product- and service development tools are normally used in situations, where a relatively stable set of requirements can be formulated as a basis for the solution. However, as pointed out several times and as documented in the empirical studies in chapter 6, the solution often comes before the understanding of the market. In the *constructivist* view, the solution emerges in a dialogue with the surroundings and the team of entrepreneurs. In Sarasvathy's *patchwork quilt* principle, the solution converges as the network of relevant stakeholders (partners, customers, suppliers) grows.

The *constructivist* perspective is not in conflict with the development methods described. It does however caution the entrepreneur to acknowledge the transient and dynamic nature of the *design object* in the entrepreneurial context. Linear, stage-based development models (e.g. [Cooper 1990]) starting from conceptualisation based on requirements and eventually leading to a finished solution, do not function well when continuously subjected to drastic changes in the designers' knowledge and the requirements coming from the network of stakeholders. Instead, the dynamic nature of the entrepreneurial process (see chapter 5) should be reconciled with the development model, which should allow for continuous re-evaluation of the solution – especially in the very early stages of the process.

Agile methods [Fowler & Highsmith 2001; Dybå & Dingsøyr 2008], although historically related to software engineering, constitute a type of development process, which is inherently dynamic and permeable to change. The notion of using PSS tools in the context of agile development processes is promising as it allows for the use of normative dimensions to build better concepts and solutions, while at the same time allowing for the necessary flexibility and agility in meeting the requirements of the ever-growing network.

The *constructivist* perspective also has another important implication for PSS designers. If meanings and behaviour are construed by interactions in the network, the PSS solution can have two different roles: One is to address and service whatever consensus/order the network reaches – i.e. a more traditional design task. The other is to design the solution to actively promote the agenda of certain stakeholders (e.g. the designers). A PSS is a potentially effective way of exerting power on- and driving translations in the actor network. This is because it is comprised of a multitude of coordinated physical, human and behavioural elements designed to be closely intertwined with the activities of the network. In short, the PSS interfaces with the actor network to a far greater extent than a product and for this reason, the designer has far more opportunities for effectuating an agenda.

PSS solutions are referred to throughout the SILP team's diary notes. However, from the entries, it seems that the team considers a very specific and quite elaborate PSS solution, which does not fare well in the eyes of the potential customer.

> *"Service system are difficult as they do not work for all types of vessels and require a huge infrastructure, which is financially difficult for a startup ventures."*

In this relation, the team could have benefitted from something like the PSS morphology, as it broadens the understanding of the solution space for the PSS. This could perhaps have led to the conceptualisation of less elaborate PSS ideas.

In terms of development processes, the SILP team choses at an early stage to use SCRUM - an agile development method, to support their project:

> *"We have made a large physical SCRUM board on which sticky notes can be placed"*

This tool was chosen as the entrepreneurs had positive experiences with using it their previous ventures. This lends credence to the idea that agile methods are more appropriate for supporting technology entrepreneurship than structured models.

7.3.2.4 SERVITIZATION OF AN ORGANISATION

As already mentioned in the previous section, the design of a PSS also involves organisational considerations, as a PSS provider needs a very different corporate structure than a product provider. The change from product-centric organisation to PSS organisation is a substantial area of PSS research called *servitization* [Baines et al. 2010; Neely 2009; Santos 2013]. The reason for this significant focus is that PSS providers typically develop from traditional manufacturing companies, whose organisation is geared toward product provision.

Again, a number of tools exist to aid in understanding the organisational elements necessary for providing a PSS. An example of such a tool for building a PSS organisation for supporting the customer's activities (or *actions*) is the *service blueprint* (SB) [Bitner et al. 2008]. The SB explicitly links the actions of the customer to *onstage* and *backstage* parts of PSS provider's organisation and network. It also provides a basis for explicitly stating the *supporting processes* needed for the organisation to sustain its PSS operations.

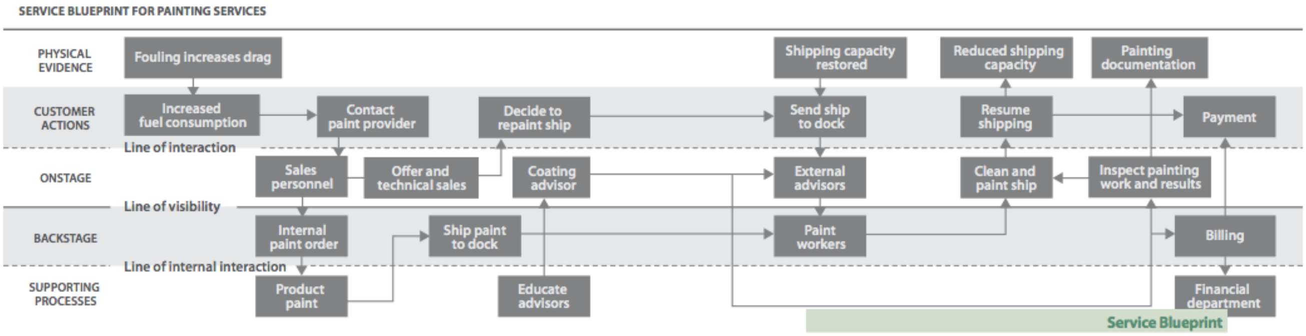


Figure 95: An example of a service blueprint for a ship painting service. [Finken et al. 2013]

Entrepreneurs will face a challenge in populating an SB as many of the relations and operating procedures are normally based on experience with a particular customer or industry. However, just as with the *business model canvas,* a model like the SB can be used to increase awareness of the *conceptual components* of a PSS organisation and for explicitly stating assumptions. Conversely, one could argue that in technology ventures the entrepreneur has the advantage of not having to adhere to existing notions of organisational structure and procedures. In this way, the venture does not require knowledge on how to change (*servitize*) an organisation. Rather, it needs knowledge on how a PSS organisation is built from scratch or as a new business unit in an existing company.

As the SILP technology project progressed, the team became increasingly knowledgeable about the technical and operational prerequisites for using integrating the SILP technology in a solution. In this relation, a *service blue print* of the organisation required to provide the solution could be useful, along with the links between the organisation and the customer's activities and the technology respectively. From the diaries, it seems that the team used the *business model canvas* to the same end.

7.3.3 RESEARCH OPPORTUNITIES IN PSS AND ENTREPRENEURIAL CONSTRUCTIVISM

The previous section outlines the potential for using various tools and methods from PSS in supporting technology entrepreneurship processes. In many instances, the methods are directly applicable, but in general, the change in underlying phenomenon from established company to entrepreneurial venture has also elucidated a number of promising venues for using the methods in different ways. The use of the normative tools and ideas from PSS could potentially help the entrepreneur in managing complexity and in developing better solutions. As such, there is a definite potential in conducting studies on the use and effect of PSS methods in the entrepreneurial process.

Furthermore, the *constructivist* nature of entrepreneurship processes poses both challenges and opportunities for PSS research. For instance, the use of PSS in driving change (*translations*) in the actor network and creating *opportunities* shows great promise and deserves further academic exploration.

The new research tool and EPR Methodology presented in chapter 5 and 6 provide an obvious platform for conducting studies on the interplay between PSS and entrepreneurship process. Indeed, the dataset might already hold data necessary for supporting such studies.

7.4 HANDLING TECHNOLOGICAL RISK

In chapter 7, the empirical evidence revealed significant differences in the processes of projects dependent on advanced technology and those less dependent on technology. Mankins' [J. C. J. Mankins 2009] technology risk assessment framework proved to be a good basis for characterising differences in the samples. Again, the PSS literature offers examples of products and technologies are affected when merged into a holistic PSS solution (e.g. [Isaksson et al. 2009]). However, unlike the sections above, these studies are generally descriptive in nature and no normative tools exist in the PSS literature to understand and managing the interaction between technology and other elements such as the actor network, activities and the organisation.

Design and innovation research has treated the topic of technology development and risk extensively [Baughn & Osborne 1989; Garcia & Calantone 2002], but the role of technology in entrepreneurship is not covered in any great detail and mostly in the form of academic entrepreneurship, where ventures are built based on research results [Litan & Song 2008; Di Gregorio & Shane 2003; Fini et al. 2010]. The frontier between technology studies and entrepreneurship process research remains under-explored and a great potential exists for better understanding the phenomenon and for developing relevant support. It has been beyond the scope of this thesis to explore this area of research.

7.5 CONCLUSION: POTENTIAL SYNERGIES BETWEEN ENTREPRENEURSHIP PROCESS AND ENGINEERING DESIGN

In this chapter, the step has been taken toward normative recommendations for entrepreneurship processes. Due to an identified kinship between entrepreneurship process phenomenon and design and innovation research/practice, the latter has been proposed as a promising field for finding tools and methods of use to technology entrepreneurs.

Specifically, the area of Product/Service-Systems has been identified as an area within engineering design with many concrete tools and methods, which can be used more or less directly as entrepreneurship process support. In this relation, a number of tools and methods have been discussed in relation to the *conceptual framework* from chapter 6. This discussion has revealed potential benefits, but also opportunities for using the tools in new ways. As such, the overlap between PSS- and entrepreneurship research shows great promise for future academic endeavours in both fields. A number of interesting venues for future research efforts have been proposed.

The chapter has also pointed out that the fields of design and innovation research and entrepreneurship currently fail to account for the role of technology in business ventures. This too constitutes a promising venue future research.

This chapter concludes the empirical and theoretical discussions of this thesis. In the final chapter, the conclusions of the thesis will be revisited and related to the research questions originally phrased.

7.6 REFLECTION ON CHAPTER CONCLUSIONS

The presence of clusters in the process data relating to *products* and *services* has been presented as a positive indication in terms of applying PSS to the field of entrepreneurship. To a scholar in design and innovation research, the area of PSS constitutes an expansion of the *design object* and a departure from the traditional product perspective. Engineering has after all historically been concerned with creating physical solutions. One could however argue that the area of entrepreneurship research does not have a similar tradition of product-centricity and that the consideration of *services* as a vessel for value creation is as much at home in the field as *products.* This begs the question; *can entrepreneurship research learn anything from PSS thinking or should it really be the other way around?* The quoted challenges met by PSS tools when faced with the constructivist reality of entrepreneurship indicate that there is some merit to this consideration.

In practical terms however, the chapter has also shown that the lack of practical and normative tools in entrepreneurship is a problem and that PSS tools and approaches – despite their shortcomings – can address this issue in several beneficial ways.

CHAPTER 8:
THESIS CONCLUSIONS AND PERSPECTIVES

RQ1.1:
What are the current challenges of Danish maritime suppliers?

RQ1.2 :
What options do the suppliers have with regard to addressing its challenges?

RQ2.1:
What type of support does the tech venture require to succeed with entrepreneurial strategies?

RQ2.2:
Can entrepreneurship research provide the necessary (process) support?

RQ2.3:
How can entrepreneurship research be strengthened to better cater to the needs of technology venture processes?

RQ3.1:
How can PSS and other design and innovation research areas be used for supporting venture- and technology development processes?

In this last chapter, the results of the thesis are summarised and discussed in terms of the research questions phrased in the first chapter. The limitations of the conclusions have been treated at length in relation each chapter's conclusion and will not be reiterated here. Finally, in closing the thesis, suggestions are made for continued efforts in the field of engineering design and entrepreneurship.

8.1 THE CHALLENGES TO THE MARITIME BRANCHE

In chapter 1, the history of the Danish maritime branch is traced and the importance of technological innovation in the success of the branch pointed out. Because of this heritage, the Danish branch remains to be the most technologically advanced in the shipping industry. However, in recent years, the branch has been severely challenged by economic downturn, closure of Danish shipyards and competition from Far Eastern suppliers, able to deliver solutions at lower prices. This insight provides an answer to the first research question:

RQ1.1:	*What are the current challenges of Danish maritime suppliers?*

This understanding of the Danish maritime suppliers' challenges forms the basis for the next research question:

RQ1.2:	*What options do the suppliers have with regard to addressing its challenges*

In response to this, two major opportunities are identified for the suppliers: One is to increase focus on the operations of vessels – as opposed to the building of vessels. The PROTEUS consortium was established to this end – i.e. to help the suppliers building Product/Service-System (PSS) solutions for supporting the shipowners' activities. The other identified opportunity is to try to leverage the technological expertise in the supplier companies and enable them to compete in terms of superior performance rather than on price. In pursuing these opportunities within PSS and advanced technology, the suppliers would have to drastically change the way they do business. To achieve this, it is argued that the organisations need to adopt entrepreneurial strategies.

To aid the suppliers in succeeding, two research paths are identified, which address central challenges to the adoption of PSS and the execution of entrepreneurial strategies. The first proposed research path is concerned with addressing a lack of understanding of the shipowners' needs in terms of PSS solutions. The other path is to develop an understanding and support for entrepreneurial venture processes depending on advanced technology. Although both paths have subsequently been followed (the first path in another research project), the focus of the present thesis is on the second path.

8.2 SUPPORTING TECHNOLOGY VENTURE PROCESSES

In the third chapter, extant research on the phenomenon of entrepreneurship is dissected in order to determine if it could provide the necessary support for entrepreneurship processes dealing with advanced technology. As the entrepreneurial venturing is a new strategy to maritime suppliers, there is a need for practice-oriented support, which can be directly applied to processes – as opposed to abstract, top down recommendations. This answers the research question:

RQ2.1:	*What type of support does the tech venture require to succeed with entrepreneurial strategies?*

The exploration of literature reveals a field of research, which has traditionally been focused on the traits of the entrepreneur and environment of entrepreneurship. The field is found to be lacking in the practical understanding of entrepreneurship processes and in particular processes dealing with advanced technology. For this reason, the field is deemed unable to currently support the maritime suppliers in their technology ventures, which answers the research question:

RQ2.2:	*Can entrepreneurship research provide the necessary (process) support?*

Subsequently, an in-depth discussion of process research in entrepreneurship and its empirical weaknesses leads to a tentative answer to the research question:

RQ2.3:	*How can entrepreneurship research be strengthened to better cater to the needs of technology venture processes?*

For the field to provide practice-relevant research and recommendations to entrepreneurs, more empirically founded studies are needed. It is further argued that the lack of empirical evidence is partly due to the lack of appropriate research tools for following the entrepreneurial process.

To address the technological shortcomings of entrepreneurship research, the area of design and innovation research is introduced, as this field has a long tradition of research on technology exploitation. In doing this, useful frameworks for understanding and categorising technological issues are found, which can be of use in strengthening the technological dimensions of the entrepreneurship process understanding.

The chapter concludes that for process and technology in entrepreneurship to be understood, new research methods are needed. This conclusion forms the basis for the methodological development and considerations in the coming chapters.

In the effort to develop a new empirical research methodology for technology entrepreneurship processes, chapter 4 uses the established understanding of the key areas *entrepreneurship* and *technology* as a platform for formulating requirements for a research tool. In the hope that existing research tools would comply with these requirements, a number of these are then compared to the list of requirements. This evaluation finds that although many tools show good compliance, none are able to meet all the requirements.

Chapter 5 proceeds to describe the conceptualisation, testing and realisation of a new automated research tool for entrepreneurship processes. The tool is designed to include favourable features of the existing research tools treated in chapter 4. After several rounds of testing and improvements, the tool is found to show good compliance with the requirements. Together with the tool, a research methodology – the Entrepreneurship Process Research (or EPR) methodology is developed. This methodology is built based on interactive data visualisations and advanced computer algorithms, which together enable qualitative and quantitative analysis of the data produced by the tool.

8.3 USING PSS AND ENGINEERING DESIGN TOOLS

In chapter 6, three studies are presented, which use the tool and the EPR methodology. The purpose of these studies is two-fold: To verify the usefulness of the tool and EPR methodology and to enable a response to the final research question:

RQ3.1:	*How can PSS and other design and innovation research areas be used for supporting venture- and technology development processes?*

The first study sought to investigate the characteristics of the studied sample (i.e. the venture projects having used the tool) and relate these to differences in activity for a pre-defined set of activity categories. This study reveals significant behavioural differences between teams, which are dependent on technology and those where technology is less of an issue. These findings clearly underline the fact that processes should be understood in more detail and that the researcher should be very much aware of the extent to which technology is important to the venture. This finding lends credence to the idea of drawing upon the technology understanding found in design and innovation research in strengthening entrepreneurship process research.

The second study has the purpose of showing how existing models for entrepreneurial behaviour can be tested empirically and thereby be validated or falsified – specifically, the theory of *effectuation* by Sarasvathy is used. The study illustrates the process of tracking heuristics derived from the theory in the data and proceeds to investigate a central hypothesis of *effectuation* – the correlation between entrepreneurial experience and the prevalence of *effectual* principles. After comparing the experience (of various types) of the entrepreneur to the prevalence of *effectual* behaviour in the process data, the study finds no clear relation between the independent and dependent variables. The study does however manage to illustrate the new method for empirically testing process theories.

The last study has the purpose of using the extensive qualitative tool dataset for building a conceptual understanding of the underlying processes. *Grounded theory* is used in conjunction with *natural language processing* and *machine learning* to find clusters of semantic similarity in the data. These clusters are then used as a basis for building a number of conceptual components and the qualitative data related to each cluster is used for understanding the relations between clusters.

This empirically based structure is translated into a *conceptual framework* for technology entrepreneurship processes. The explanatory power of the *framework* is then verified by applying it to a historical case of technology entrepreneurship in the maritime branch. This entirely empirical approach to theory building shows that meaning can indeed be drawn from the entrepreneurial process by using the new tool in conjunction with the EPR methodology.

In the 7th chapter of the thesis, the potential for applying knowledge and methods from the design and innovation research field is discussed. Here it is argued that the entrepreneur is in many ways comparable to a designer – only, the *design object* of the entrepreneur is inherently complex and holistic. Despite sharing traits, entrepreneurship research has failed to provide the insights and support needed for the entrepreneur to *design* his/her new business.

Seeing that the practical processes involved in translating needs and ideas into actual products (and services) are at the core of design and innovation research, it is concluded that the area of engineering design holds a wealth of descriptive and normative methods, which could be of benefit to the entrepreneur.

In particular, the area of PSS research and practice is found to contain a number of tools and methods, which provide the necessary complexity and breadth for entrepreneurial design. To substantiate this claim, a number of PSS tools and methods are introduced and discussed in terms of the new *conceptual framework*. This discussion concludes that the tools treated are indeed potentially useful to the entrepreneur. Furthermore, it is found that the *constructivist* and dynamic nature of the entrepreneurship phenomenon can be seen as both a challenge and an opportunity for the tools, which in certain cases will have to adapt to serve the entrepreneur.

Finally, the chapter discusses the potential for using the extant knowledge of technology development from design and innovation research as a basis for improving the understanding of technology in entrepreneurship processes. Aside from the technology risk framework by Mankins, no concrete methods and tools are found, which could be directly used in this new context. As such, the intersection between technology and entrepreneurship process constitutes an interesting and largely unexplored academic frontier.

As a response to RQ3.1, these conclusions show several examples of how and where design and innovation research can be used in supporting technology entrepreneurship processes. This also completes the validation of the hypothesis phrased in chapter 2 (page 26):

> ***H1:*** *Entrepreneurial processes dealing with advanced technology can benefit from the tools and methods found in design and innovation research in general and PSS in particular.*

8.4 FUTURE STUDIES IN ENGINEERING DESIGN AND ENTREPRENEURSHIP PROCESS RESEARCH

This thesis has endeavoured to contribute to the methodological basis for understanding the phenomenon of technology entrepreneurship processes. It has also identified a number of areas in which design and innovation research and entrepreneurship process research can be brought together in new valuable research efforts. In this overlap between research fields, the entrepreneur is a designer and entrepreneurship is seen as a process of designing.

There is a large potential in furthering the understanding of this overlap, as practical tools for supporting these crucial processes are few and far apart. If Danish maritime suppliers are to follow the entrepreneurial route to prosperity, a concrete understanding of the implications is needed.

The data capture tool and entrepreneurship process research methodology developed in this thesis provide a new opportunity for further exploration of the overlap between the two fields. The following research questions are examples of future research efforts, which could be of great value to Danish maritime suppliers and other organisations looking to build new ventures based on advanced technology:

PSS and entrepreneurship processes:

- How can PSS ideas and tools be changed to better suit entrepreneurial objectives?
- Which role can PSS frameworks and tools play in the construction of entrepreneurial opportunities?
- Can the normative tools of PSS be used in improving the quality of solutions developed by entrepreneurs?

Technology and entrepreneurship processes:

- How is technological risk described in relation to other risk components in entrepreneurial ventures?
- When does it make sense for an entrepreneurial venture to focus on technology development?
- How should technological development steps be prioritised in relation to other parts of business development?
- How can technological risk be mitigated in the entrepreneurial process?

The maritime branch and entrepreneurship processes:

- How do maritime companies adopting entrepreneurial strategies perform in comparison to companies adopting conservative strategies?
- What does the development process look like in a maritime venture looking to exploit new technology?
- Where do Danish maritime suppliers have an advantage over their competitors?

8.5 RECOMMENDATIONS TO MARITIME SUPPLIERS

The recommendation of this thesis is that the Danish maritime suppliers should succeed by way of entrepreneurial venturing based on radical innovation instead of cost-cutting strategies. The reason for this recommendation is the latent potential that lies in the technological knowledge of the Danish maritime suppliers and their historically strong relation (and adjacency) to the customer – the shipowner.

Even if processes are optimised using robots and lean management systems, the Danish suppliers will still be at a disadvantage in competing on cost. Instead, the competitive advantage should lie in superior value creation through superior technological solutions and extensive support of the customers' activities and emerging needs. This will require a departure from the current way of doing business as well as new technical solutions. Addressing new opportunities by way of new means is the domain if entrepreneurship.

In chapter 7 (section 7.3.2, page 179) it was argued that PSS tools could offer support for many of the activities that a maritime venture face in trying to exploit new technology. These tools not only help the process; they also improve the transparency of the process by providing structured and visual representations of central components (solution, customer activities, organisation etc.). This improves the management's ability to follow the development of the venture. This transparency is further improved if the maritime venture uses the EPR tool as support for the process.

It is not the intention of the author to suggest that such entrepreneurial strategies should replace the existing operational strategies of the maritime suppliers. As was argued in section 2.6 (page 24), such *radical innovation* projects belong in separate, small and nimble organisations, which on the longer term can grow in importance and become an important part of the company's business.

As also argued in section 2.6 and later when analysing the SILP technology case (section 6.5.1, page 163), it is crucial that a technological venture has the necessary technology and market knowledge/competencies. For this reason, any technology venture organisation should feature specialists from the man organisation. Indeed, the obvious strategy would be for the maritime supplier to build the whole venture team form existing employees. It is however not likely that these employees have any experience with entrepreneurial venturing and a suggestion would be to train employees in entrepreneurial competencies.

An interesting alternative could be to invite external stakeholders with entrepreneurial experience/training to aid in progressing the venture. One way of doing this is to employ the help of students. In this thesis, the course on technology entrepreneurship has been mentioned several times. Such a course provides a unique basis for enrolling team members (students) with training in entrepreneurship to work free of charge on building the venture. As shown in Table 15132), the course routinely produces new promising, technology-based businesses - in the maritime branch and other industries.

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