Developing a framework based on past innovation mechanisms

Master's thesis in Product Development

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Abstract

This thesis aims to improve innovation rates at Mycronic AB, a company which has seen a decrease in their innovation rates over the last several years, compared to past development efforts. The thesis therefore investigates innovations mechanisms from past innovative projects, with the intent of reusing this knowledge, in the form of a visual framework. The thesis also studies past projects through a knowledge management (KM) perspective to understand if potential barriers towards reusing these innovation mechanisms could explain the decrease in innovation rate seen today.

A literature study was performed to deepen the understanding of the field of knowledge management, and technology management, and especially what is important for innovation in a company. This knowledge would then serve as a foundation for a case study, which was used to investigate innovation mechanisms and barriers from past projects. Based on the result of the case study a visual framework could be created. This framework presents the identified innovation mechanisms, both positive and negative, alongside the innovation process which was identified for these projects. The framework could be used to support activities aimed at innovation or used to encourage innovation in general. The framework could also be used to establish R&D activities with the goal of increasing innovation. By implementing the framework into the organization, it could be possible to encourage a sustained innovative culture in the long term.

The identified barriers could, in part, explain why the company has been unable to reuse the knowledge from these past projects. The identified barriers can serve as a starting point for continued work with KM. Overcoming these barriers could over time improve innovation.

Keywords: Innovation, Innovation mechanism, Knowledge management, Technology management, Framework, Product development

Preface

This master thesis concludes the master's program in Product Development at Chalmers University of Technology in Gothenburg. This thesis was offered by Mycronic AB after contacting them in the fall of 2018. After initially discussing the aim and scope of the project, an interest for this subject arose. The title was chosen to "Developing a framework based on past innovation mechanisms" and the thesis was conducted between 2019-01-21 to 2019-06-14.

We could not have performed this work without the aid of key individuals both at Mycronic and Chalmers and we would therefore like to express our gratitude.

We would like to thank our supervisor at Chalmers, **Dag Bergsjö**, associate professor at the division of Product Development, for the advice and insights provided during the duration of this thesis.

We would also like to thank all the interviewees who took time out of their schedule to help us perform our case study and other employees at Mycronic who described the company's products to us.

Lastly, we would like to thank our company supervisor, **Lars Ivansen**, expert systems engineering, for all knowledge he shared which was instrumental in completing this thesis work. He was always readily available to answer our questions and provide us with invaluable feedback.

This thesis has been challenging and educational and has provided us both with increased interest within the field of technology management and knowledge management.

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1. Introduction

To introduce this report, a background and problem description will be given. Then the aim, objective and scope of the project will be presented.

1.1. Background

In a competitive environment, with rapidly shifting markets and leaps in technology, it's important for companies to be flexible and to rise to the many challenges related to product development (Wheelwright & Clark, 1992; Ulrich & Eppinger, 2012; Simsit, Vayvay and Özturk, 2014; Teece, 1996). This means that companies must be able to adapt to new technologies and organizational forms (Teece, 1996). The lead time for development of new products and technologies is decreasing at a rapid pace as companies compete to market their product before their competitors and as product life cycles decrease (Wheelwright & Clark, 1992). All of this puts high demands on a company's ability to develop new products and processes in order to stay relevant in today's global economy (Vos, Keizer & Halman, 1998; Wheelwright & Clark, 1992). Different approaches and methods exist to help improve the product development process over time. In this project the focus will lie upon how an organization manages its knowledge and technology resources to improve innovation.

Knowledge is increasingly important as a resource for driving innovation in companies (Nonaka, 1994). Knowledge can provide a company with a more sustainable competitive advantage compared to products or technology (Davenport & Prusak, 1998; Yang, 2010; Nonaka, 1991). This is partly due to the availability of technology and also because a competitor could match the quality and price of products existing on the market over time. However, matching the knowledge behind these products or technologies is not as easily done. This knowledge could in turn be used, if managed correctly, to create new products by the time the competitors have caught up (Davenport & Prusak, 1998). This means that tangible assets such as products or manufacturing equipment are not as important today and that intangible assets such as knowledge are more critical for the success of companies (Yang, 2010). Nonaka (1991) also claims that this is the only certain source of competitive advantage. The organization needs to create an environment and infrastructure that inspires its employees to capture and reuse knowledge in an effective and easy way through technologies, tools and methods (Catic, 2018; Bergsjö, Catic & Stenholm, 2016; Gold, Malhotra, & Segars, 2001). If the created knowledge is not captured, the company runs the risk of repeating mistakes from previous development projects or having to recreate the same knowledge again (Catic, 2018). This could lead to significant delays and increased development costs. This "knowledge waste" is commonly observed in companies today and make up for a large amount of time from each development project (Kennedy, 2008). The activity involving creating, capturing and promoting knowledge reuse is called Knowledge management (KM). Effective KM could improve a company's performance since it directly improves processes such as innovation (King, 2009)

Another important resource for an organization to manage in order to stay ahead of its competitors is technology. Because of this, it's important for an organization to have access to leading technologies and to develop a strategy for managing technology (Wheelwright & Clark, 1992). The organization's ability to adapt and implement acquired or developed technologies will be dependent on its strategy for technology management (Philbin, 2013). These strategies must identify which technologies are important for the company's technical capability, and how this knowledge can be used to improve its products and processes (Wheelwright and Clark 1992). The technology management practices of the company need to ensure that this strategy aligns with the company's current and future needs (Phaal, Farrukh & Probert, 2004).

KM and technology management could therefore help a company identify important gaps in knowledge and skills. In the context of product development, gaps in knowledge are commonly referred to as areas where new knowledge and skills are required to solve various problems within the organization (Vos, Keizer and Halman, 1998). By identifying these gaps, actions can be taken to close the gaps and thus improve product and process innovation. Mycronic has identified gaps in their knowledge or understanding of what made the company innovative during their most successful product development efforts in the past. By closing these knowledge gaps, Mycronic hopes to understand what fostered innovation in the past and then reuse this knowledge in future development projects.

1.2. Problem description

This project was conducted together with the technology development department at Mycronic, a leading supplier of high-tech manufacturing equipment for the electronics industry. Mycronic has seen a decline in innovation rates throughout their development efforts compared to the early days of the company. In 2007 the company received an award by IEEE spectrum which ranked Mycronic's patent portfolio no. 6 in the semiconductor equipment manufacturing industry. Since then the company has seen a downwards trend in number of patent applications and this is a trend the company aims to turn around. Therefore, innovation mechanisms and knowledge that inspired technological breakthroughs in the past as well as barriers that restrained these breakthroughs were investigated.

By investigating innovative projects from the company's past, innovations mechanisms that drove innovation in these projects, could be understood. This knowledge could then be used to create a framework which will inspire and sponsor innovation in future development efforts. Based on the problem description, the following research questions were aimed to be answered:

RQ1: What have been the key innovation mechanisms behind major technological breakthroughs in Mycronic's past?

With Mycronic experiencing a decline in innovation, it's of interest to investigate what fostered innovation in the past, i.e. the innovation mechanisms. By identifying what these innovation mechanisms are, it's possible to reuse this knowledge to foster innovation in future projects.

RQ2: How can a visual framework, based on previous innovation mechanisms, be used to support an innovation and technology development process?

This visual framework will present the identified innovation mechanisms and describe how they fit into a possible innovation process. The framework aims to provide a quick overview of the innovation process together with the identified innovation mechanisms to foster a general innovation climate, or serve as a guide for how the company can work to inspire innovation.

RQ3: What have been potential barriers that prevented capture and reuse of the identified innovation mechanisms?

This research question aims to explore potential barriers, which could have contributed to the reduction in innovation rate experienced by the company today. The investigation will take on a KM perspective, examining the levels of personalization and codification during these projects, and how these could have affected innovation today.

1.3. Aim

This thesis aims to investigate the company's previous innovation mechanisms to understand what made previous projects innovative. This knowledge will then be used to foster innovation in future development efforts, through the use of a visual framework. The thesis also aims to understand underlying barriers which have prevented the reuse of previous innovation mechanisms and thus explain why the innovation rates have decreased.

1.4. Objectives

The objective of this thesis is to identify triggers, which have led to major technology breakthroughs within the product and technology development at Mycronic in the past. The knowledge about the innovation triggers will then be used to design a framework to classify or model technological breakthroughs visually. The purpose of this framework is to propose ways of inspiring, prioritizing and sponsoring innovation, without compromising the ability to successfully transfer mature technology into products. The objective is also to highlight barriers, which could have had an impact on the decreased innovation rate experienced today.

1.5. Scope

The project is limited to include only technological innovation and does not investigate other kinds of innovation. The study will also only include Mycronic's products that are designed and produced at the Täby site, this limitation is due to the timeframe of the project. These products include photo mask writers, direct writers, placement equipment and jet printing equipment. The timeframe of this project also limits the possibility to expand this investigation to include other companies than Mycronic. This thesis further only investigates past projects, not how the company is organized today or how they currently work with innovation.

This project is limited to a total of 20 working weeks of 40 h, see appendix 1 for time schedule. There is no specified budget available for the project and financial resources are limited to what the company and the school are willing to sponsor.

2. Method

In an effort to answer the research questions posed in the previous chapter, a greater understanding of the field of knowledge management, and technology management was needed. This understanding was achieved through a literature study of the respective fields. With the intent of determining what made Mycronic innovative in the past, a case study was also conducted at the company. During the case study, both interviews and document studies were performed. The work has mostly been conducted at Chalmers University of Technology, with several visits to the company headquarters in Stockholm.

This is a master thesis in collaboration with a company where the authors have no prior relationship with the company in question. The authors are therefore outsiders who are collaborating with employees at the company. This reduces the likelihood of any bias towards the result presented in this thesis. A level of bias could still occur since collaboration with employees is necessary, who could introduce bias in favor of the company when discussing certain events. This potential risk of bias needs to be considered when analyzing the results of the case study, particularly the interview results.

2.1. Literature Study

Literature studies can not only be used to gather information, but can also be used as evidence. It is also often possible to make deeper conclusions about the information than what is explicitly written, meaning it is possible to make interpretations of the text (Denscombe, 2014).

When deciding on what articles to read and what sources to use it’s important to consider the credibility of these sources. A quality indicator for academic journals is if the articles have been reviewed. This does however not guarantee that the sources are credible. To get the most credibility of the used journals as possible, these journals should have existed for some time, they should have been published by a professional association and there should be a clear statement that these articles have been peer reviewed. For books it could be beneficial to use publications that have several editions or university press publishers. Internet sources and web pages are more difficult to evaluate since there is a lack of restrictions online. There are however some factors to what make a credible online source. Credibility is given if the website is owned by a university or a government, if the website seems trustworthy, if it is up-to-date and if it is popular (Denscombe, 2014).

The literature study was carried out by using the Chalmers University of Technology library data base. Different keywords such as “Knowledge Management”, “Technology Management” and “Technology innovation”, were used to determine what is important for innovation and knowledge management in a company. The credibility was assured by only searching for peer-reviewed articles and by using multiple sources to strengthen certain claims.

2.2 Case Study

Case studies investigate the different events, relationships, experiences and processes for one or a few different phenomenon occurrences. It is more a qualitative research method than a quantitative one. Though, case studies typically look into unique cases, a more general view can often be found by generalizing the results. When performing a case study, it's important to have a narrow focus and to have a depth, to prevent important insights from being overlooked. An advantage of using case studies is that details on both the problem and the underlying reasons to the problems are explored. Case studies also allow a wide range of different methods to be used alongside it, making it possible to adapt it to the specific needs of the project (Denscombe, 2014). To be able to draw more general conclusions that apply to all or most projects in the company, several cases were studied in a so called "Multiple-Case Study". This is a case study type, where a set of cases are considered and then cross-case conclusions are drawn (Yin, 2014). Yin (2014) argues that it's difficult to generalize when only one case is considered and that case studies should be considered more like experiments, where replication of the results is sought. If the same conclusions can be drawn from multiple different cases, this creates credibility for the generalized conclusions (Yin, 2014). This approach was suitable during this study, since a more general result was sought. By using this approach, general innovation mechanisms could be found and then applied to the company as a whole.

During the case study several previous development projects were studied, both through interviews and document studies, to determine what made Mycronic innovative in the past. A case study was performed since it allows for a general overview of several years of development projects and allows conclusions to be made regarding the technological development processes at the company. During the interview segment of the case study, several innovative projects could be identified. These projects were then made the focus of a document study, to further support the results of the interviews and to identify positive and negative deviations which could have had an impact on innovation. The document study was also used to identify barriers which could have contributed to a decrease in innovation. This was believed to be the most efficient given the time limit of the project.

2.2.1. Interviews

Interviews are beneficial to use to investigate complex issues where qualitative facts such as experiences and opinions are important. The structure of an interview can be divided based on the flexibility of the interview. The interviews can be structured, semi-structured or unstructured. A structured interview is a controlled interview where the researcher has prepared a list of questions. These questions are designed to provide a direct response. In a semi-structured interview, the researcher has several questions needing answers, but instead of direct questions the questions are more open-ended, allowing the interviewee to more freely explore and discuss the topics presented by the researcher. An unstructured interview takes the approach of a semi-structured interview even further, placing even more focus on letting the interviewee lead the conversation. In this case, the researcher's role is to introduce a topic and let the interviewee freely explore the topic (Denscombe, 2014).

Interviews have been used in this project since it allowed face-to-face communication with people who were part of the early development projects at Mycronic and it was believed that their personal insights and experiences could help understand how innovation occurred at the company in the past. The structure that was used in this project was semi-structured, one-to-one, interviews, because of the open-ended character of the problem. Rather than answers to specified questions, it was believed that it would be beneficial to more freely explore the technology development process, while at the same time have some clear topics to discuss. This is because the sought answers are complex processes involving many experiences and relationships. This way the interviews could be performed on the interviewees' terms and at a time that fit their schedule. The interviews targeted people responsible for technological development of previous projects, because this was deemed to be the richest sources of information to help answer the research questions. In total 14 interviews were conducted, averaging 60 minutes per interview. The interview guide is presented in Appendix 2 (in Swedish).

2.2.2. Document study

Documents can be considered a source of information where the data is in the form of a written text or preserved in some other way. Examples of different documents are articles, reports, discussion forums, pictures and videos. Documents can be used as evidence of a certain event or to answer questions regarding a certain event or situation. One important property of a document is that the information exists long after the moment when the information was first created. It is however important to determine the validity of the document before making use if it's data. Several documents should be compared to determine if the presented data is a good representation of the topic being studied (Denscombe, 2014; Patel & Davidson, 2011).

The document study was used as a compliment to the interviews to further explore innovation mechanisms at Mycronic. This data source is also not reliant on the memories of the interviewees which makes it more accurate over time. The documents that have been used in the document study were available through a VPN link to the company's data library and were therefore also easily accessible.

The document study was conducted by searching three different file servers used by Mycronic at the time of the studied cases. These three servers provided the bulk of the documents that were analyzed during this study. Along with the three file servers, the shared workspace Confluence was also used. Additional information was located on a large discussion forum supported by Lotus notes. These five sources of documents were too vast to thoroughly search within the scope of this project, and thus a general search for patterns and deviations related to innovation was conducted.

3. Societal, ethical and ecological aspects

Mycronic follows several sustainability guidelines which were necessary to consider when conducting this project. By promoting more technological innovation in the company, the social, ethical and ecological aspects could have been affected. The framework was required to comply with Mycronic's policy regarding sustainability in their technology creation.

This policy includes e.g. the notion that it's important to understand and communicate sustainability aspects of the design throughout the organization, to suppliers and to customers. Communicating sustainability aspects could inspire others to follow. All stakeholders must also be informed of potential risks. Product quality is also an important ecological sustainability aspect, which refers to the lifetime of the proposed technology and competing technologies. Prolonged product lifetime typically results in less need for spare parts. Further, this thesis was required not to promote the use of any hazardous substances in the manufacturing of Mycronic's products. Compliance with "Restriction of Hazardous material" (RoHS), the REACH regulation and the Batteries Directive was therefore necessary. The WEEE Directive is also highly relevant for the company and any efforts that were made during this project ought not to have negative effects on the recyclability and reusability of future machines. It was also important to consider the energy consumption over the product lifecycle, backwards compatibility, recycled materials and design for serviceability. Other important aspects included the use of local suppliers and the reduction of mass and size of both the products and the packaging to reduce emissions from transport.

Additional possible effects from a framework that fosters innovation include, that this could lead to a more automated production process, resulting in employees losing their jobs in the future. Further, the framework was required to not have a negative effect on Mycronic's inspection and approval of suppliers, with regards to child labor, ensuring that the prohibition for employing children remained. Yet another aspect that was important to not be affected negatively, is Mycronic's policy to avoid conflict materials that can risk violating the human rights law.

An ethical aspect that was considered with regards to the work method is to always ask the interviewees if they consent with being interviewed. The interviewee should never be forced into doing an interview and if they agree, they must be aware of what information might be used in the study. Using audio recording during the interviews is also a sensitive issue and the interviewees must always be asked beforehand if it's acceptable to record the interview (Denscombe, 2014). Something else that was considered regarding the work method was to keep the answers anonymous so that the interviewee's opinions or comments wouldn't affect them or their position in the company. The subject that was discussed is however not sensitive or emotional, but it involved people criticizing other people and working processes.

4. Theory

In this chapter the findings of the literature study are presented, including information regarding knowledge management, technology management, existing innovation frameworks and an explanation of the NTCP framework.

4.1. Knowledge Management

Knowledge is often described in literature as being connected with data and information, however it is important to understand that these concepts are not the same. Understanding the difference between these concepts and knowing which is needed in a specific situation is important for the success of an organization (Davenport & Prusak, 1998). These three concepts are often connected in a “knowledge hierarchy”. This hierarchy is depicted as a pyramid with data as the foundation, followed by information and then knowledge (Rowley, 2007). Data can be described as the fundamental building block for producing information, which is consistent with its placement in the knowledge hierarchy (Davenport & Prusak, 1998). Information is therefore created when meaning, e.g. context, is added to data. Knowledge exists within the minds of individuals (Davenport & Prusak, 1998; King, 2009), this means that information is transformed into knowledge when individuals are working with information and its implications (Davenport & Prusak, 1998). However, organizations are critical for developing this knowledge beyond the individual (Nonaka, 1994). When the right knowledge is used at the right time it could have a significant impact on the efficiency of a company’s product development and help support important business strategies (Davenport & Prusak, 1998).

Knowledge can be explicit, tacit or something in between. Explicit knowledge is knowledge that is articulated, put into writing or depicted in figures. Tacit knowledge is knowledge that isn’t expressed in words, that is tied to individuals’ intuition, senses or mental models. Tacit knowledge is often skills that the owner cannot express, but yet possesses. Because this type of knowledge is more tied to unarticulated skills, it’s more difficult to communicate and to access by others (Nonaka & Von Krogh, 2009; Nonaka, 1991).

4.1.1. Knowledge life cycles

Knowledge management can be described in terms of different life cycles as knowledge is created and used within an organization. These life cycle stages, aim to outline processes needed for an effective KM within the organization. One example of a KM lifecycle is the model described by Davenport and Prusak (1998), which involves generation of knowledge, codification of knowledge and transfer of knowledge. Heisig (2009) has investigated several definitions and concludes that the six most common activities when managing knowledge are: Sharing, Creating, Using, Storing and Identifying. It’s important to know that knowledge needs to be treated differently throughout its life cycle as the knowledge is created, captured, and reused, see Figure 11 (Catic, 2018; Bergsjö, Catic & Stenholm, 2016).

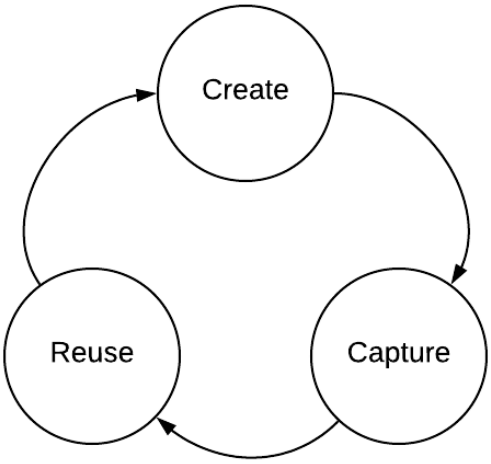

Figure 11: Knowledge life cycle

Knowledge Creation

Nonaka (1991) claims that knowledge is created through the interaction of explicit and tacit knowledge. This interaction is described with four different patterns, which combine the possible interactions between tacit and explicit knowledge to turn existing knowledge into new knowledge. Knowledge is therefore created through interactions between individuals (socialization), by combing sources of explicit knowledge (combination), through the translation of tacit knowledge into explicit knowledge (externalization) and through the translation of explicit knowledge into tacit knowledge (internalization). All of these different patterns are connected and play a role in creating knowledge. Externalization is an important step in this process and can be especially difficult to achieve (Nonaka, 1991).

The knowledge creation process of making tacit knowledge into explicit knowledge could be made possible through the use of metaphors, analogies and models. Metaphors serve to link contradicting ideas and help individuals understand something more intuitively. Analogies then help refine the knowledge creation process by clarifying the different ideas captured within the metaphors and how they relate, as well as by acknowledging contradictions. The last step in this process is the creation of a model. This step is the most systematic and logical of the processes and solves any contradictions and makes the concept real through a model. This model is then used as a knowledge transfer medium throughout the company. This knowledge creation process, built up by interaction between tacit and explicit knowledge, could mean changes to a company's organizational structure but will in turn provide the company with a process which could improve innovation (Nonaka, 1991).

The process of knowledge generation is generally an unsystematic activity and is difficult to grasp by companies. Successful generation of knowledge is achieved, not by focusing on the knowledge generation processes, but rather by focusing on the environment in which these processes take place (Davenport & Prusak, 1998). Nonaka (1991) describes the invention of new knowledge, not as a special process, but rather as a way of behaving or being, in which everyone is a knowledge worker. The creation of new knowledge means the re-creation of the entire company, both on an organizational and individual level. Since the knowledge creation happens within the minds of the individuals it is important to have an organizational structure and managerial practices that support this human resource (Nonaka, 1991).

Knowledge Capture

Tacit knowledge has a high significance for a company's knowledge capital, which makes a strategy for capturing this knowledge important (Davenport & Prusak, 1998; Blessing & Wallace, 2000). Knowledge codification is the process in which organizational knowledge is transformed into knowledge that can be used by those who have a use for it. The knowledge is made accessible and user-friendly to ease to reuse of knowledge. However, codification of knowledge does have some difficulties, including how the knowledge can be put into a simpler, more focused form and yet not lose the dynamics and ways of interpreting the original data. A structure that allows for preservation of these properties is therefore necessary (Davenport & Prusak, 1998).

It would require too much effort to codify all of the organization's knowledge and the risk of trying to achieve this is that the relevance of the knowledge is lost (Davenport & Prusak, 1998). It's far more important to keep the knowledge relevant than trying to codify a large quantity of knowledge. The scope should be narrow enough to keep the knowledge relevant and to make it usable, however it should be wide enough to include knowledge that for example has the potential of being useful in the future (Davenport & Prusak, 1998; Blessing & Wallace, 2000).

Tacit knowledge is difficult to codify, it is a complex process to capture this type of knowledge in writing or in figures (Davenport & Prusak, 1998). However, the externalization process described in the last section, using metaphors, analogies and models, can aid the codification process of tacit knowledge (Nonaka, 1991). Providing access to people with tacit knowledge is another effective way to capture this type of knowledge (Davenport & Prusak, 1998). Capturing this type of knowledge is important to ensure that the knowledge is retained even if the knowledge owner leaves the company (Stenholm, Landahl & Bergsjö, 2014; Davenport & Prusak, 1998). It is also important for the availability of the knowledge. The access to the tacit knowledge is restricted to the availability of the knowledge owner. If the owner is occupied at a specific time, the knowledge is inaccessible (Davenport & Prusak, 1998).

Knowledge Reuse

As the size and complexity of the company increases, the likelihood of specific knowledge existing within the company, increases. However, this also decreases the likelihood of the knowledge being shared since people try to seek out knowledge in their immediate surroundings or since it's difficult to know where the knowledge is located (Davenport & Prusak, 1998).

Knowledge transfer which is spontaneous and unstructured, and which happens through face-to-face meetings, when people get together and talk about work, problems, and exchange ideas, are a vital part a company's knowledge transfer and in turn success (Davenport & Prusak, 1998). If knowledge is transferred to a larger extent, this also tends to create new knowledge as the person receiving the knowledge, reflects on it (Yang, 2010). It is therefore important to develop strategies which encourage these types of face-to-face meetings and to not see it as wasted time. However, knowledge transferred in this way, is not guaranteed to reach all parts of the organization, especially if the company is large. A more formal way of transferring knowledge is therefore needed. Tacit knowledge is difficult to handle and requires special consideration. It could for instance be transferred by rotating people within the organization and have them apply their knowledge to different projects. IT systems could be used to support the transfer of this type of knowledge, but it should not replace the physical interaction between people. An important factor for successful knowledge transfer is a common language and common ground, e.g. mechanical engineers are more likely to transfer knowledge to another mechanical engineer. Beyond this, the knowledge transfer process or method must be made to fit the company culture for it to enable effective transfer of knowledge and an infrastructure should be used which supports the reuse of knowledge (Davenport & Prusak, 1998).

4.1.2. Knowledge management infrastructures

Heisig (2009) has made a comparison of 160 different knowledge management frameworks and concluded that there in general are four major categories of context factors that can be linked to the success of knowledge management efforts. These context factors should be considered in equal parts, to optimize the performance. The list below shows these context factors:

1. Human-oriented factors: culture-people-leadership.
2. Organization: process and structure.
3. Technology: infrastructure and applications.
4. Management process: strategy, goals and measurement.

The different context factors mentioned by Heisig (2009) permeate the knowledge management efforts in companies and the different aspects that are described can also be expressed in terms of different infrastructures. Gold, Malhotra and Segars (2001) mentions three different infrastructures that can be used to strengthen the knowledge management processes in a company, namely the technical, structural and cultural infrastructures.

The technical infrastructure consists of IT-systems that integrate different systems for information and communication flows. This can alleviate communication by removing barriers between employees and can allow companies to create, transfer and store knowledge efficiently (Gold, Malhotra & Segars, 2001). Herschel and Jones (2005) argue that knowledge management data bases are crucial for an organization. These data bases gather, analyze and store knowledge that exists in an organization so that this knowledge can be used to gain a competitive advantage over other companies on the market. Through efficient storing and analyzing, the information that is kept in these data bases can increase in value. One downside and a challenge with this type of software is that it is difficult to store non-quantitative data, even though 80% of business information consists of non-quantitative data (Herschel & Jones, 2005). Having an IT-system does however not guarantee success of knowledge management. The organization must also have a knowledge-based mindset and actively work with trying to convert tacit knowledge into explicit knowledge for the IT-system to be beneficial (Yang, 2010).

The structural infrastructure describes how the organization should be structured. To support knowledge management, the organization should be flexible. Knowledge should be shared across borders and not kept inside the individual functions. When the organization is more rigid, a lack of knowledge transfer between functions or divisions can occur, even though the knowledge transfer is efficient within each function. Rewards and incentives could also be designed so that they encourage knowledge creation and sharing (Gold, Malhotra & Segars, 2001; Yang, 2010). These reward systems are critical for how employees behave and if designed correctly, they will encourage employees to work with the different knowledge management tools and principals (Yang, 2010). Yang (2010) claims that it's important to recognize individual efforts of employees and at the same time have a common goal for the group and rewards that are based on the outcome of the projects, to encourage team work.

The last infrastructure is the cultural infrastructure, which addresses corporate culture as a central part of knowledge management efforts (Gold, Malhotra & Segars, 2001). According to Gold, Malhotra and Segars (2011), an important part for supporting knowledge sharing within this infrastructure is to encourage dialogues between individuals, both formal and informal. It's important to have a short geographical distance between colleagues for spontaneous meetings to occur. If the distance between people is larger than roughly 20 meters, the chance of these meetings occurring, becomes significantly lower (Trygg, 2017). Gold, Malhotra and Segars (2011) also argue that a clear corporate vision is needed to create a sense of purpose and a direction for the whole organization. The culture further tends to change toward enabling open conversation when there is trust among employees and no fear of making mistakes (Gold, Malhotra & Segars, 2001; Herschel & Jones, 2005; Davenport & Prusak, 1998).

Herschel and Jones (2005) claim that a common mistake is thinking that knowledge-sharing initiatives will change company culture. There can be a resistance from employees to share their knowledge because they are rewarded for being knowledgeable and sharing this knowledge can decrease the value of the individual in the eyes of the organization (Herschel & Jones, 2005; Yang, 2010). Instead change needs to start with top management, which must be active participants in the effort of changing the culture towards promoting knowledge sharing (Herschel & Jones, 2005). This claim is supported by Wheelwright and Clark (1992) who talk about the importance of top management's involvement in bringing about organizational change. The employees can be inspired by the actions of the top management. Herschel and Jones (2005) further claim that culture is responsible for enabling knowledge sharing between the company and external partners and suppliers. This knowledge sharing is important since not all knowledge exists within the organization itself (Gold, Malhotra & Segars, 2001).

4.2. Technology management

Technology can be identified in a number of ways, it can therefore be helpful to view technology as a special form of knowledge (Phaal, Farrukh & Probert, 2004). Technology then refers to specific engineering knowledge, both theoretical and practical, skills and artifact used to develop products and services (Mishra & Srinivasan, 2005; Burgelman & Siegel, 2008). Technology can be embodied in people, materials, cognitive and physical processes, plant, equipment and tools, and thus technological knowledge is comprised of both explicit and tacit knowledge (Burgelman & Siegel, 2008; Phaal, Farrukh & Probert, 2004). By defining technology as a special kind of knowledge the KM concepts presented above could also apply to improve the management of technology (Phaal, Farrukh & Probert, 2004).

The process, in which this technology knowledge is applied to introduce new product and services on the market, can be called technology management. Technology management therefore provides processes or strategies for aligning technical issues and capabilities with the company's strategic business decisions (Phaal, Farrukh & Probert, 2004; Wheelwright & Clarke, 1992; Philbin, 2013). Technology management is relevant to a number of business processes, including innovation which is the focus of this thesis (Phaal, Farrukh & Probert, 2004).

4.2.1. Technology innovation

Innovation can be considered as a new idea being put to use, which means that the idea itself is not innovation, but rather the practical application of it (Mishra & Srinivasan, 2005; Stock, Greis & Fischer, 2002; Damanpour, 1987). Technology innovation, using the definition of technology above, can be defined as new technology or new combinations of technology that are used in products, services, production processes or delivery methods (Mishra & Srinivasan, 2005; Stock, Greis & Fischer, 2002). Innovation in the production processes is crucial for sustained competitive advantage as product innovations typically are infrequent (Mishra & Srinivasan, 2005). Applying something new to a company can also be considered innovation, even if it's commonly used by other companies in the industry already. Innovation can be viewed as a way for companies to adapt to an evolving environment and a way to increase its performance level. How ideas are generated does not directly affect how well a company performs and thus a change can be considered innovation if it's new to only the adopting company (Damanpour, 1987). To be able to achieve a sustained competitive advantage, it's important to consider technology innovation and strategic management together. Achieving this integration is possible through identification of patterns for breakthrough innovation and combining these with the company's strategic plans (Mishra & Srinivasan, 2005).

There are different ways of achieving innovation for companies, namely systemic innovation and autonomous innovation. Systemic innovation is where the company actively pursues innovation through different development projects. The alternative is to have autonomous innovation, where innovation is not actively pursued, but instead generated through daily work tasks. There are also different kinds of innovation, called radical innovation and incremental innovation. Radical innovation is where a completely new approach is used, while incremental innovation is where many small changes, such as added features, together lead to innovation (Mishra & Srinivasan, 2005; Simsit, Vayvay & Özturk, 2014). Phaal, Farrukh and Probert (2004) mention that S-curves can be used to describe the dynamics of incremental and radical innovation, see Figure 12.

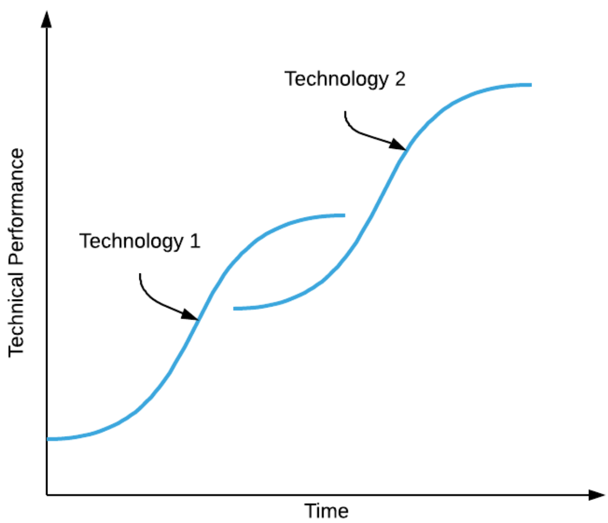

Figure 12: Technology S-curves

These curves visualize how technical performance evolves over time. Radical improvements become scarcer as time progresses due to limited financial resources and due to technical constraints. This means that alternative solutions to the problems can start competing with the dominant design (Phaal, Farrukh & Probert, 2004). Eventually a new solution will overtake the old solution in technical performance and become the new dominant design, this is then called a disruptive technology (Christensen, 1997; Phaal, Farrukh & Probert, 2004). This dynamic calls for more constant flows of innovation, instead of sporadic innovation. It's important to work with both incremental and radical innovation flows to maximize the technical performance (Phaal, Farrukh & Probert, 2004).

However, the notion of incremental and radical innovation has been criticized as being incomplete or even misleading (Henderson & Clark, 1990). Instead of classifying innovation in term of radical or incremental, Henderson and Clark (1990), classify innovation in the terms of components or system architecture. Innovation at a component level is described as the most common since product development projects tend to divide the development effort into subgroups, where each subgroup is responsible for a component. This organizational structure therefore provides a structure in which innovation at a component level works well. Innovation at an architectural level, where none of the components are changed, can prove more difficult, since this could fundamentally change the organizational structure of the company, and thus disrupt how the company develops at a component level. This could in turn create a barrier towards innovation since the company would have to learn new ways of cooperating and communicating (Henderson & Clark, 1990; Christensen, 1997).

The innovation of a company could also be affected by the competitive environment in which it operates (Mishra & Srinivasan, 2005; Davenport & Prusak, 1998). A company with monopoly can get more profit from products because they can limit the amount of technology that is imitated by other companies. This added profit can then be used to further invest in research (Mishra & Srinivasan, 2005). However, according to Teece (1996), this is not always the case. This is because, companies that operate in a competitive environment can match funding to important projects just as well as companies with monopoly. Monopolistic companies do typically have higher cash flows, but there are several other variables that affect how well funding can be matched to projects. Transaction costs between employees in the form of compensations and promotions is one example of something that can affect this. Multiproduct companies are another exception to this as these companies can fund a product in one market with funding received from sales in another market. Lack of financial resources can also be compensated with inter-company cooperation, through for example joint ventures or co-production (Teece, 1996; Suematsu, 2014). There are also examples of companies who have upright benefited from a competitive environment. Competition can foster innovation because companies are forced to innovate to survive. Companies which have monopoly might not have the same pressure to innovate and thus the innovation rates can fall (Mishra & Srinivasan, 2005). A company can try to introduce an artificial sense of crisis or set up goals that need to be overcome to try to inspire innovation (Davenport & Prusak, 1998). Though, too much competitive pressure can force companies to release new products or services before the innovation has matured, risking a less innovative product or service being released on the market. Technology innovation can also arise from innovation in other products or services. A new product or service on the market can create demand for improvements in other products and services and thus foster innovation (Mishra & Srinivasan, 2005).

The company's organization is also an area which could affect innovation. Hierarchies and bureaucracy often create slow organizations which are not well suited for innovation. These organizational structures also often have poor incentives to innovate (Mishra & Srinivasan, 2005). One way of dividing different organizational structures is to use the terms "mechanistic structure" and "organic structure". Mechanistic structures utilize rules and standardized activities to see to that employees work in a specific way. There is often a rigid division of departments and a clear chain of command. This can achieve high operational efficiency and less follow up from managers, but can impact the creativity negatively. Organic structures are less rigid and are often characterized by cross functional and cross hierarchical teams. This organizational structure is well suited for creativity and exploration, but can yield more varying outcomes and thereby be less efficient in that manner (Trygg, 2017). Examples of cross functional teams are heavyweight teams and autonomous teams described by Wheelwright and Clark (1992). Heavyweight teams have managers, who have high influence on resources and evaluation of team members, though team members also report to functional managers. Autonomous teams, on the other hand, are self-contained and the project manager has full control over allocated resources. This type of team can also use own rules and policies, which are set by the team (Wheelwright & Clark, 1992). Some success factors for cross-functional teams are that there are less than 10 core team members, that team members remain in the project for its full duration and that team members are collocated (Trygg, 2017). Additionally, the richest type of information exchange, and thereby the preferred type for cross-functional communication, is face-to-face communication. Documents instead have more sparse transfer of information (Wheelwright & Clark, 1992).

The culture of the company is also important and it's beneficial to have an organizational structure which supports this culture. One thing that nurtures creativity in the company is to have a culture where it is accepted to fail and where employees feel secure taking risks. Furthermore, the incentive systems could be designed in a way that motivates innovation. As with any development efforts, a customer focus is also a powerful force for innovation. In this effort, it's important to understand what the future needs of customers will be and to make sure that these needs are formulated in a way that is helpful for detailed development work or decisions (Wheelwright & Clark, 1992). Beyond this, there is also a correlation between company size and innovation (Mishra & Srinivasan, 2005). There are arguments that smaller companies are more flexible and that they therefore can adapt to changes more easily. Smaller companies can avoid the bureaucracy that is present in larger companies and can adapt to changing markets. There are also arguments that say that motivation may be higher for employees in smaller companies, because the individual's performance is better recognized and compensated for, through for example, payments in stock. The work that is put in by employees is also more likely to show in the company's overall performance, which could be linked to motivation (Phaal, Farrukh & Probert, 2004). However, there are also arguments for why larger companies have higher levels of innovation. One argument is that large companies have a greater potential to aid a large number of innovations. This is due the fact that large companies have a greater technical knowledge, both diverse and specialized. They also have a larger number of skilled workers with a greater product development experience. Large companies can also provide greater financial support and better tolerate unsuccessful innovation compared to smaller companies (Damanpour, 1992; Stock, Greis & Fischer, 2002).

There are different ways of measuring the rate of innovation. The financial resources put into R&D efforts can be used as a measure, but this doesn't measure the results or consider the effectiveness of the development process (Phaal, Farrukh & Probert, 2004). At Mycronic, the number of patentable ideas that are handed in to their patent council, are measured to see changes in innovation. This can be considered better than the measurement of financial resources, but is still criticized by Stock, Greis and Fischer (2002) for not considering how many of these ideas that become new products or processes. Stock, Greis and Fischer (2002) connect technological performance with innovation performance to measure the effectiveness of the innovation process. This measurement thus recognizes innovation as the application of ideas into product which then are sold on the market.

4.2.2. Technology Forecasting

Technology forecasting can, according to Martino (1993) be defined as the prediction of future characteristics of useful machines, procedures or techniques. Technology forecasting is a necessity for a company operating in an environment where technological change is crucial for maintaining a competitive advantage (Philbin, 2013; An & Ahn, 2016). Technology forecasting could improve a company's innovation by improving the quality of decisions being made (Martino, 1993). Technology forecasting and its impact on Mycronic's innovation in the past is therefore of interest for this thesis.

An example of a successful forecasting done by Mycronic is their entrance on the display market. Mycronic received a request from a research institute in Finland where the researcher asked if Mycronic was able to produce large photo masks. The researcher had noticed a shift towards using photo masks for display manufacturing instead of for semiconductors, and a collaboration started. Mycronic was then approached by LG who wanted to use photo masks to manufacture a shadow mask, which was used in the display technology at this time. Mycronic wanted to utilize their knowledge from making semiconductors to produce photo masks used for shadow mask fabrication. This proved to be a challenging task since the production process produced systematic errors in the photo masks. These errors resulted in a striped picture being displayed on the screens. Mycronic eventually solved this problem and started their rise as market leaders, selling manufacturing equipment for display manufacturing. This technology has since then been adapted to reflect the change in market demands, starting with the shift towards flat screen TV, followed by LCD, and now OLED technology.

4.3. The diamond approach (NTCP)

The diamond approach (or the NTCP model) is a framework for successful growth and innovation (see Figure 13). It illuminates that different projects should be managed differently depending on a number of characteristics. Depending on the project type, the projects can be allotted different amounts of resources and these resources can be used in a more efficient way more closely related to the priorities of that specific type of project. Projects of different types can also more accurately be compared with one another (Shenhar & Dvir, 2007). The different characteristics that are used to distinguish the projects are:

- Novelty

  The novelty characteristic can be viewed as the degree of change to the product or the manufacturing processes. In the NTCP model, there are three different levels for this. Derivative projects comprise of small improvements that are made to existing projects. Platform projects are instead a bit larger in size and include creating a next-generation product, based on the existing product. Lastly, Breakthrough projects are used to create products that are totally new and that customers haven't experienced before (Shenhar & Dvir, 2007; Wheelwright & Clark, 1992).

- Technology uncertainty

  The different projects can also be distinguished based on the level of technology in the projects. Technologies that are well-established are defined as low-tech, whilst medium-tech projects are projects where existing technologies are used, but some new features are added. In high-tech projects, technology is used, which is new to the company, yet exists and don't have to be developed during the project. Super-high-tech projects instead include having to develop the required technologies within the scope of the project (Shenhar & Dvir, 2007).

- Project complexity

  Project complexity is yet another characteristic, which can be used to categorize projects. Projects with low complexity are called Assembly projects, where existing technologies are assembled together to a new whole. The next level of complexity is called System projects, which is a complex assembly of several interacting technologies or subsystems of technologies. Lastly, there are the Array projects, which consist of several different interacting systems (Shenhar & Dvir, 2007).

- Pace

  The pace characteristic describes how important the time aspect is in the projects. The success of Regular projects is not dependent on if the project is done exactly on time or not. For Fast/Competitive projects, time is important to be able to compete on the market or to seize opportunities. Time-critical projects instead need to be completed on a certain day to not miss a specific opportunity. Blitz projects are projects that are used to put out fires and to solve crises (Shenhar & Dvir, 2007).

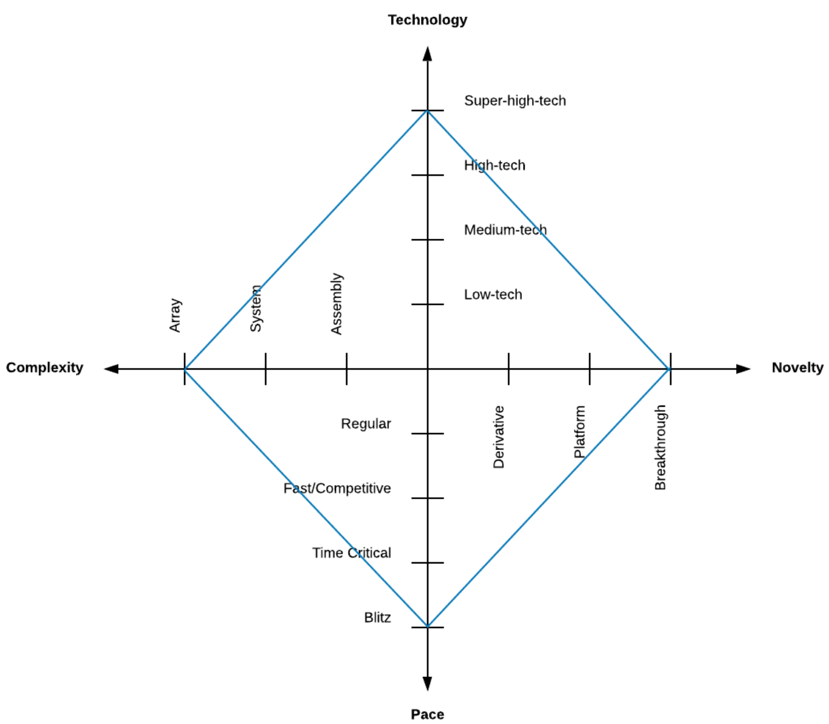

Figure 13: The NTCP Framework

5. Company case descriptions

Mycronic AB is a leading supplier of high-tech manufacturing equipment for the electronics industry. It's a Swedish company and the headquarters are located in Täby, Stockholm. Mycronic has however over 1200 employees and a local presence in over 50 countries. It has existed for over 40 years and was in the beginning two different companies, namely Micronic Laser Systems and MYDATA AB. Micronic Laser Systems developed pattern generators for both the display market and the semiconductor market. MYDATA AB developed Assembly solutions for assembly of circuit boards. During this time, Micronic Laser Systems also had an office in Gothenburg, where part of the development was done. In 2009, the two companies become one and eventually the name was changed to Mycronic AB.

The different cases were chosen to cover Mycronic's two business areas, Assembly Solutions and Pattern Generators, from a historical perspective to attempt to understand what made the company innovative, as well as understand how innovation rates changed over time. The case study began by investigating Mycronic's (then called Micronic Laser Systems) development of their first mask writer for display manufacturing in the early 90: s. This part in Mycronic's history marks a significant turning point for the company. During this time the company went from a period of financial difficulties, to becoming the leading manufacturer of mask writers for the display market.

The Sigma project was an attempt made by Mycronic to reenter the semiconductor market. This was aided by the knowledge gained during the development of pattern generators for the display market combined with increasing market requirements. The aim of the Sigma project was to develop a photo mask writer for integrated circuit fabrication using, for Mycronic, a new technology called spatial light modulator (SLM).

The ejector project belongs to the business area of Assembly Solutions, which originally was a part of the company called MYDATA AB. This project was studied to understand the innovation mechanisms at MYDATA and also how the merge affected innovation in the new company.

The Rosetta project and the implementation of the Rosetta concept called "Gamer" was an attempt to unify the different data path architectures used in the pattern generators. This project was a company initiative which, compared to the other studied projects, did not have a customer focus. The Rosetta/Gamer projects were also tightly connected with a project for developing a direct writer using "Laser Direct Imaging" (LDI), which was a highly innovative project. The LDI project is therefore also presented in the Rosetta/Gamer case.

5.1. Photo mask writer for display manufacturing

This machine manufactures photo masks, which in turn are used for the manufacturing of displays. The scan is generated in an acousto-optic crystal, where a high frequency sound wave reflects the laser beam. This movement is totally electronically controlled, which yields efficient control of beam precision and excellent image quality. The features are created by controlling the laser light that exposes the photo mask blank. The modulation of the beam is done in another acousto-optic crystal. When the laser scan has covered the whole surface, the photo mask is completed and can be used in subsequent steps performed by Mycronic's customers for manufacturing of displays, see Figure 1.

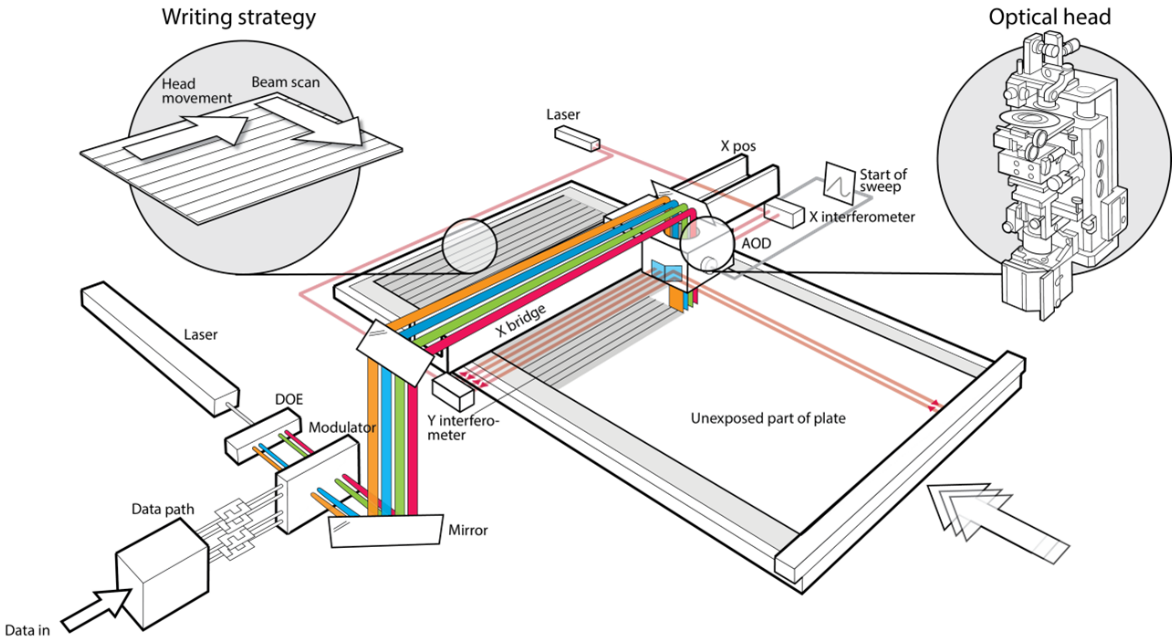

Figure 1: Depiction of the photo mask writer technology (Picture by curtesy of Mycronic AB)

The projects studied related to this case are of the platform kind. The fundamental basic machine already existed and new versions or generations of this machine were developed. The technologies that were used were available, but not well-established in the company, making the technology uncertainty high. The machine was complicated and involved many different subsystems that had to be integrated into a working system. During this time, there were also some threats in the form of competing companies, which meant that the faster the product was completed, the higher chance there was to compete with these competitors. The most important project characteristics are summarized in Table 1 below, where the novelty, technology, complexity and pace are graded according to the levels provided in the NTCP framework.

Table 1: Project characteristics, photo mask writer for display manufacturing

Photo mask writer for display manufacturing	
Time period	1990-2000
Novelty	Platform
Technology	High-tech
Complexity	System
Pace	Fast/Competitive

The information related to the NTCP framework in the table, can then also be presented in a graphical form as seen in figure 2.

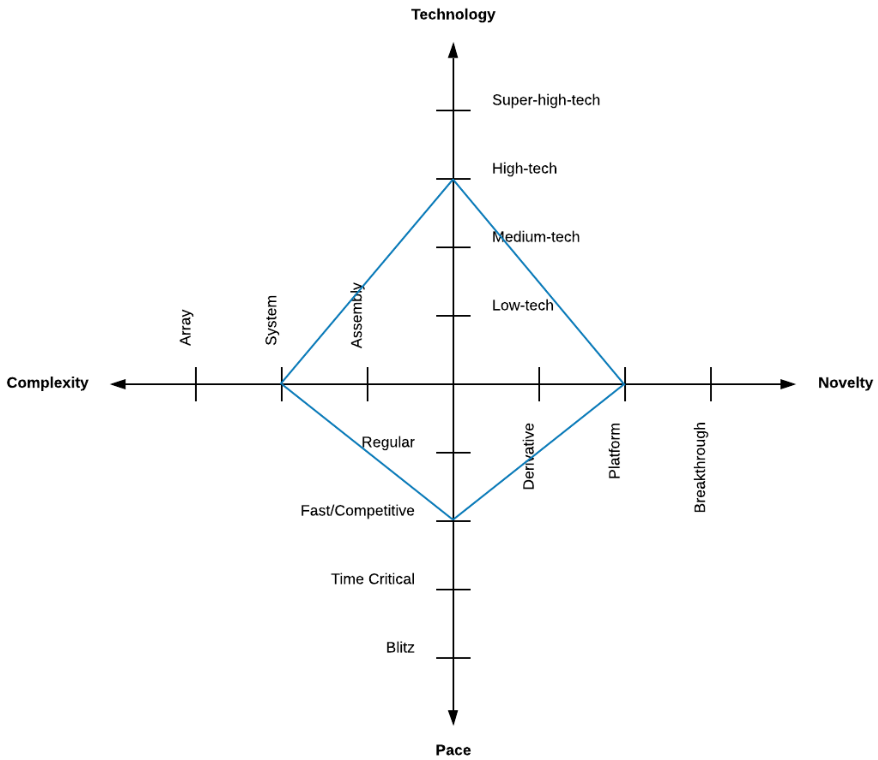

Figure 2: The photo mask writer projects from an NTCP perspective

5.2. The Sigma project

The “Sigma” project was an effort made by Mycronic to further establish themselves on the semiconductor market. The predecessor to the Sigma project was called Omega. Sigma can be seen as a branch off from Omega where new technology was explored, while at the same time keeping many of the systems developed for Omega. The Sigma machine was based on spatial light modulator technology (SLM) developed in cooperation with the Fraunhofer institute in Dresden, Germany. The SLM technology models the light through diffraction. The SLM is a microchip with millions of small mirrors, which are individually controlled using D/A converters, each with calibrated transfer functions. Each mirror can tilt up to a quarter of the light's wavelength and thus control the intensity of the light. A pattern is preloaded onto the chip and a laser pulse is reflected by the mirrors. The reflected beam is then transformed into a real image downstream in the machine at an aperture. The aperture lets some of the reflected light from the mirrors through to form a contrast image. This image is then projected, through a focusing lens, onto a photo mask blank. This process is then repeated to produce the entire photo mask, see figure 3.

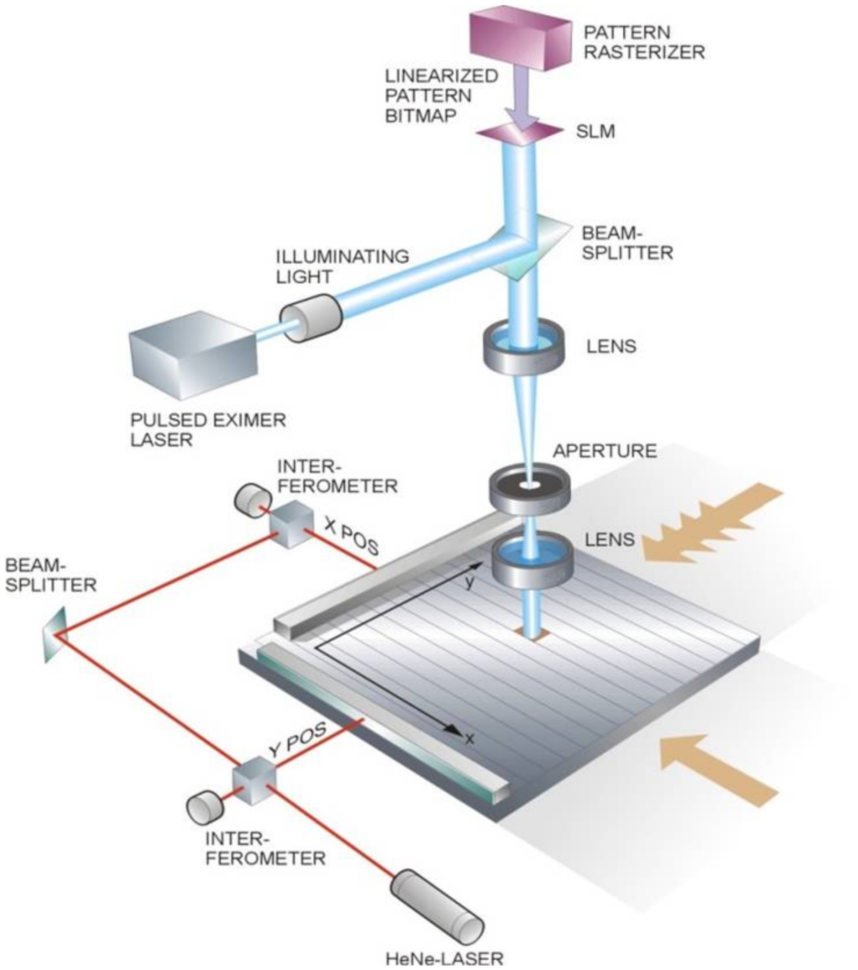

Figure 3: Depiction of photo mask production using the SLM technology (Picture by curtesy of Mycronic AB)

This project introduced new technology to an already existing machine and was therefore practically a next generation product. The new technology had to be developed within the project and the different subsystems then had to work together in the finished product. There was also a time pressure in the form of a market opportunity, related to a tool-selection by Intel. Relevant project characteristics have been summarized in Table 2 below.

Table 2: Project characteristics for the Sigma project

Photo mask writer for semiconductor manufacturing	
Time period	1999-2011
Novelty	Platform
Technology	Super-high-tech
Complexity	System
Pace	Fast/Competitive

With the information presented in Table 2 it is possible to relate the Sigma project to the NTCP framework, see Figure 4.

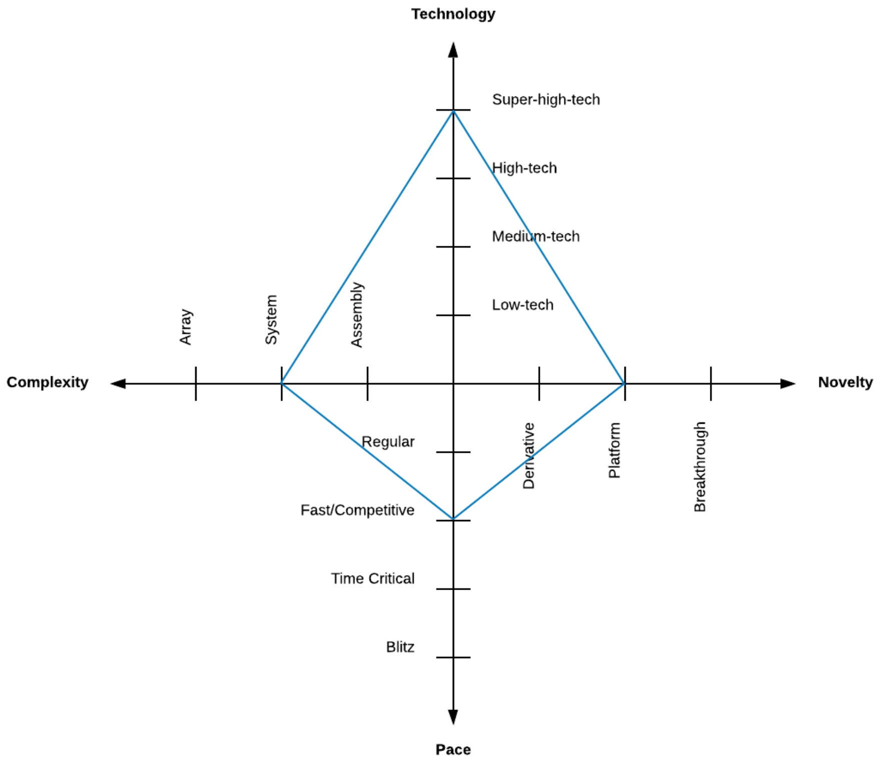

Figure 4: The Sigma project from an NTCP perspective.

5.3. The ejector project

The jet printing and placement equipment side of the business was at this time a company called MYDATA. Jet printing is the process in which a circuit board is provided with solder paste in places where the different components will be placed in succeeding processes. This is done with a jet printing machine using an ejector, through which the paste is shot in nanoliter droplets onto to the circuit board, see Figure 5.

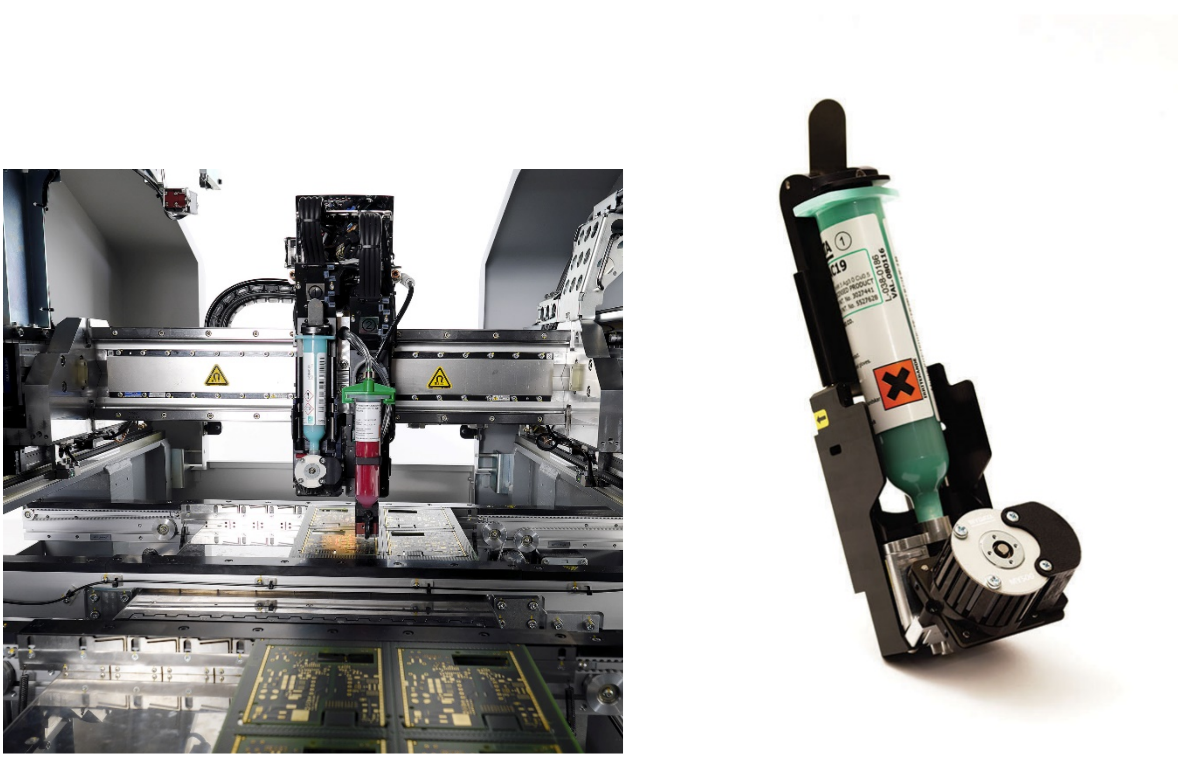

Figure 5: The ejector component (Picture by curtesy of Mycronic AB)

The ejector component has been developed in derivative projects, with small changes over a long period of time. New technology had to be developed within the scope of the project and the different components then had to be assembled into a working subsystem for the jet printing machine. These projects operated at a regular pace and had no particular outside time pressure. The most important project characteristics are presented in Table 3 below.

Table 3: Project characteristics for the ejector project

Jet printing	
Time period	2005-2009
Novelty	Derivative
Technology	Super-high-tech
Complexity	Assembly
Pace	Regular

With the information presented in Table 3 it is possible to relate the ejector projects to the NTCP framework, see Figure 6.

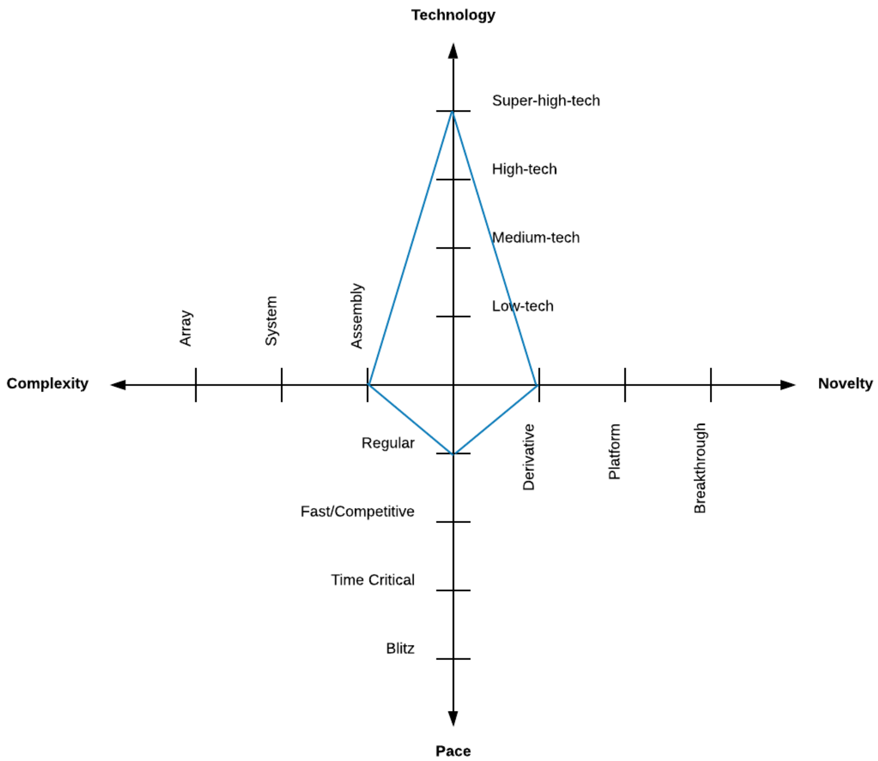

Figure 6: The ejector projects from an NTCP perspective

5.4. Rosetta/Gamer and Laser direct imaging (LDI)

The Rosetta project was, as described earlier, an attempt to unify the different data path architectures used in the pattern generators. Mycronic felt the need to upgrade their current data path architecture since it was based on older technology and was failing to meet cost per performance ratio for profitability when scaling up to next generation platforms. This architecture did not perform well enough on the current platform either. This project was also driven by the possibility to unify or reduce the number of data processing platforms used at Mycronic at this time. Mycronic hoped to utilize the advancement made in the area of high-performance computation to support their current and future requirements placed on this new data path architecture, special interest was placed on accelerator technology in the form of graphics processing units (GPU's). A partitioning of Rosettas' domains can be seen in Figure 7.

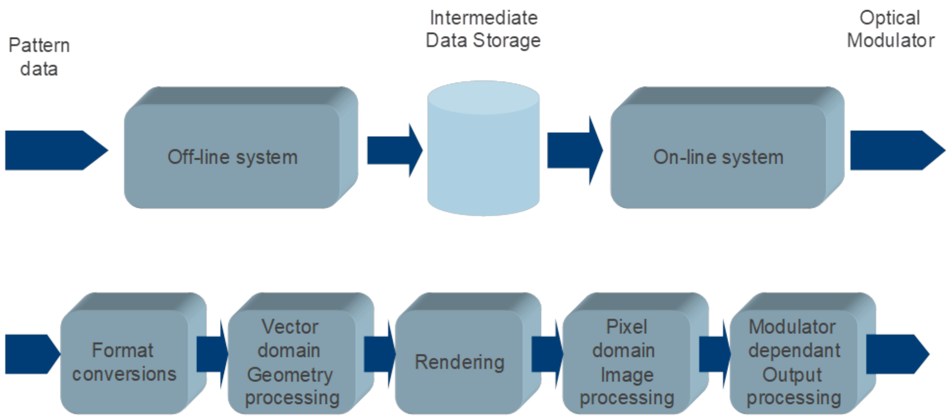

Figure 7: Rosetta data path (Picture by curtesy of Mycronic AB)

During the Rosetta project a proof of concept for a data path architecture was suggested and proven. The concept developed during Rosetta was then implemented through a project called "Gamer". This served as the first implementation of the new data path architecture and would serve as a working component for the LDI project. The LDI project was an attempt to create a direct writer for the manufacturing of advanced printed circuit boards. It exposed patterns directly on substrates at very high speeds, see Figure 8. In this case study, only the implementation of Gamer in LDI was studied and not the LDI project itself.

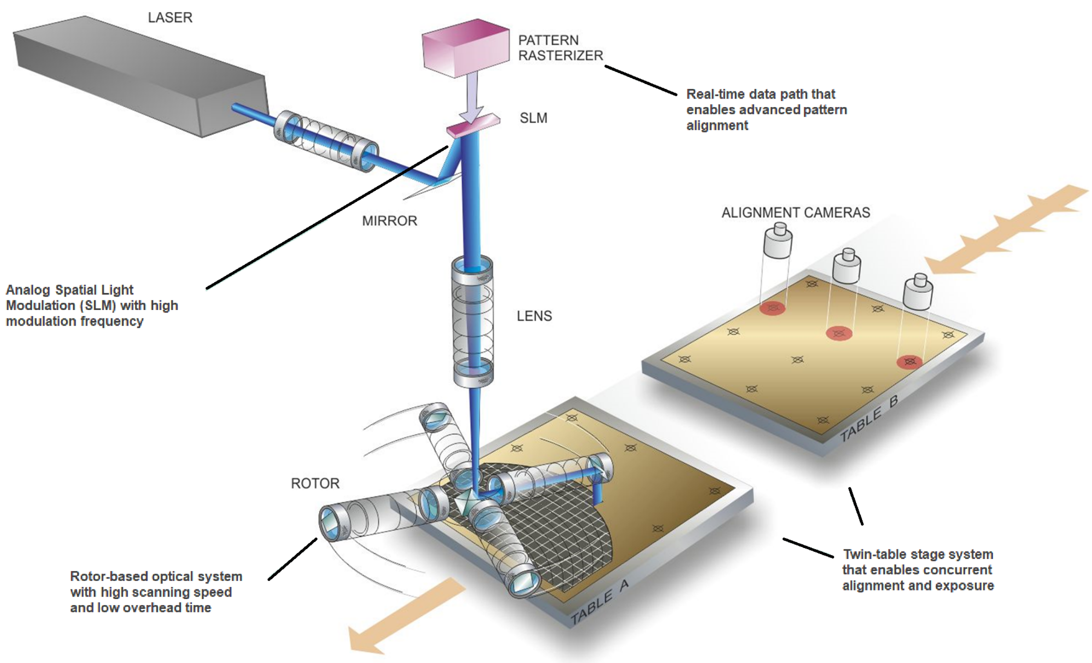

Figure 8: Depiction of the LDI machine (Picture by curtesy of Mycronic AB)

The Rosetta/Gamer project was a platform project, which aimed to create a new foundation from which new products could be developed in the future. Some new technologies were used, but mostly, this was a rework of the existing architecture, where the existing elements were put together in a more efficient way. This project was not customer driven and purely a company initiative to ease future development efforts, meaning no significant time-criticality. These project characteristics have been summarized in Table 4 below.

Table 4: Project characteristics for the Rosetta/Gamer project

Rosetta/Gamer	
Time period	2008-2010
Novelty	Platform
Technology	Medium-tech
Complexity	Assembly
Pace	Regular

From Table 4, a visual depiction can be made related to the NTCP framework, see Figure 9.

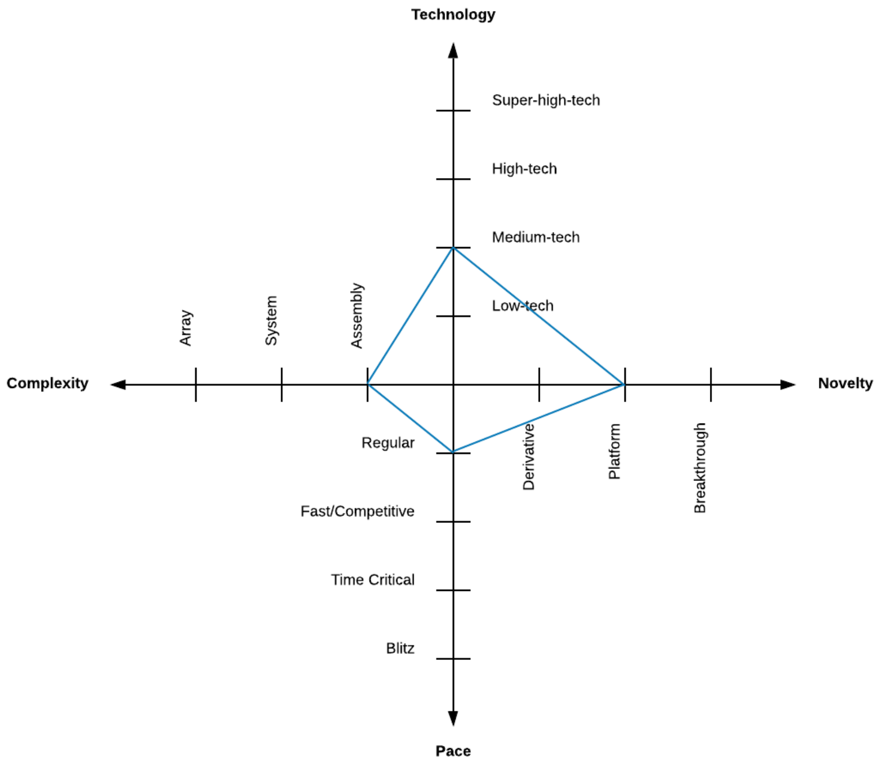

Figure 9: The Rosetta/Gamer project from an NTCP perspective

Though this case study only relates to the implementation of Gamer in LDI, it can be helpful to consider which type of project the LDI project was. The LDI machine was a completely new product, with a totally new way to produce photo masks. The needed technologies had to be developed during the project and different subsystems then had to be assembled into a total system. The project was also time-critical since the company needed Intel to choose their product to get accepted in the industry. A summary of important project characteristics can be seen in Table 5 below.

Table 5: Project characteristics for the LDI project

Laser Direct Imaging (LDI)	
Time period	2010-2012
Novelty	Breakthrough
Technology	Super-high-tech
Complexity	System
Pace	Time-critical

The characteristics in Table 5 can be visualized using the NTCP framework presented in Figure 10.

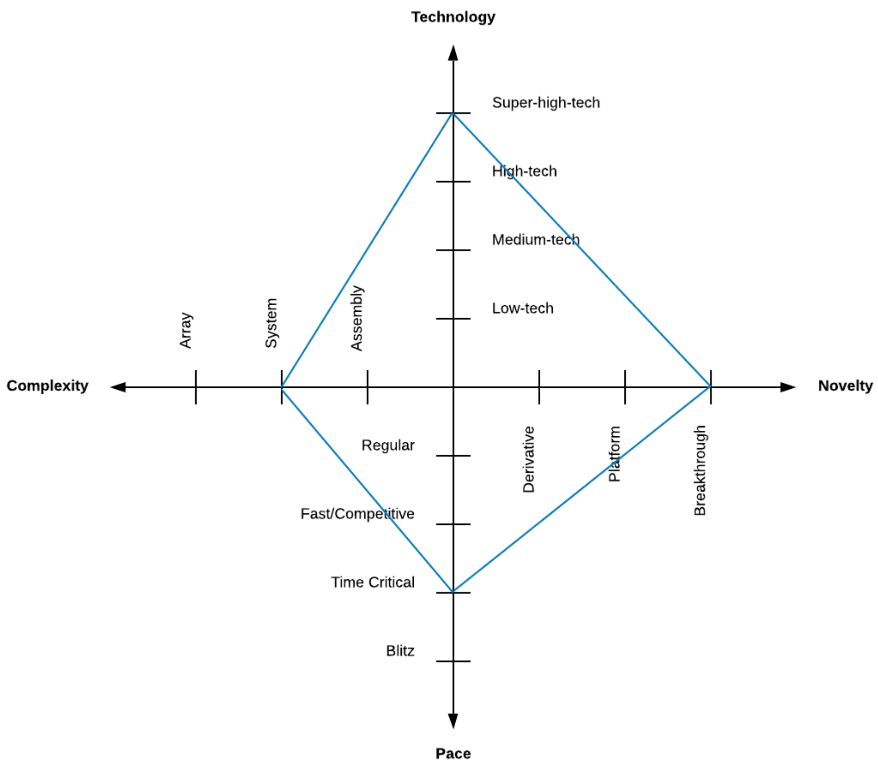

Figure 10: The LDI project from an NTCP perspective

6. Results

In this chapter, the results from the interviews and document studies will be presented for the different cases separately followed by a summary of the entire case study which highlights the important finding from all cases.

6.1. Photo mask writer for display manufacturing

The result of the case study related to the photo mask writer for display manufacturing is presented below.

6.1.1. Interviews

All interviewees remember the communication between colleagues as being informal and direct, often face-to-face and with frequent group discussions. The white board was described as a popular, and often used tool to aid communication of ideas and problems. When direct communication was not possible, email was used.

The relationships between colleagues were unanimously described as open and trusting. During the time the company had around 30 employees and everyone knew each other and got along well. The working environment was described as helpful, everyone provided help to solve tasks or problems outside their own areas of responsibility when needed. A common remark related to this subject was that the willingness to help still is deeply rooted within the company. However, the possibility to help others is more limited today due to stricter project follow-ups and administrative work. The stress levels during this period of time were described as high, with most interviewees describing this stress as something positive, which was pushing innovation forward. However, a smaller part of the interviewees described the stress levels as a negative influence on innovation since there was less time for exploring different ideas. More people quitting their jobs due to stress was also an observed development during this time, however the employee turnover was described as low.

Each employee's role in the company was less defined during this time, and having several areas of responsibility was not uncommon during the earliest projects. This was described as something positive since this created people with a fundamental understanding of the machine they were building. This made performing tests and experiments easier. Interviewees that had stayed with the company for a long time reported that the number of individuals with this broad knowledge diminished over time, not only making tests more time consuming to perform, but also reducing the sense of unity since these individuals worked across disciplines. The hierarchy within the company was described as informal or completely absent, especially during the earliest projects. This structure improved communication and relationships with managers, who were considered colleagues more than managers.

There was a high reliance on individuals and their skills to innovate rather they reliance on processes or methods. The use of processes appears to have increased over time, which many interviewees felt was restrictive and unhelpful for innovation. These early projects were described as having a focus on the product being developed, the goal of the project was to build a functional machine and deliver it to a customer. No strict project model was followed to help direct the development process. This product focus was described by some interviewees as being a more innovative environment, and even a better working environment. When the company had few employees, the development and delivery of a machine to a customer, engaged the entire company. Smaller team sizes were generally used as the company grew. These teams consisted of 5-15 people of varying educational backgrounds, mostly PhDs or engineers with master's degrees. The interviewees all reported that smaller team sizes were preferred since this made it easier to communicate, and thus made the teams more effective.

The top management and head of research were described as supportive and helped drive innovation forward in the early days of the company. Management trusted their employees to do good work, and little individual follow-up was done. Interviewees who had stayed with the company for a long time reported, as mentioned before, that this has changed, with more follow-up and administrative work being placed on each employee.

Mycronic has retained a leading position on manufacturing equipment for the display market, and this monopolistic situation was reported to not have had any negative impact on their innovation. On the contrary, some interviewees reported a motivation to retain this position. It was also reported that a large monetary gain could be had for an increase in performance of the machines, which was describe as a motivation.

All interviewees mentioned that problems and ideas often arose in contact with customers and their needs. This customer contact was more common during this time compared to today, and this was described as something positive since it provided a greater understanding of the problem at hand, and thus fostered innovation. It was also common to try to solve problems with the machine through physical experimentation and tests. Most interviewees mentioned that an initial idea often arose within an individual, and later was improved upon during a group discussion. Almost all interviewees mentioned that it was positive to share ideas with colleagues. There also appears to have been a larger acceptance for employees to work on their own projects outside the commercial projects, or explore alternative solutions. This was often credited to the organizational structure the company had at that time, with employees having less defined roles and a trusting management that believed this could be valuable. Most interviewees believe time for exploring their own ideas is good for innovation. It was also common for potentially good ideas, not to be explored further. The reason for this was reported to be; lack of time, economical unjustifiability or no structure for reviewing the idea.

All interviewees reported that they felt a strong motivation and interest in developing these products due to the high technology level and complex challenges. There was also a general interest in understanding and solving the customer problem. The financial compensation for writing a patent was frequently mentioned as an incentive towards actually writing a patent, however several people added that they did not consider this important for innovation. What drove them was the pride of solving the problem. Below is a summary of the most frequent topics of discussion during these interviews;

- Interdisciplinary communication was common.
- Communication was informal, and face-to-face. Meetings were also common.
- Positive and accepting atmosphere between colleagues, close relationships and high trust and helpfulness.
- High stress levels, which mostly was talked about in a positive sense.
- Less defined areas of responsibility and informal hierarchy.
- Fewer processes, which was considered good for innovation.
- Projects were driven by goals, products and deliveries, rather than by a project model.
- Small teams, more effective and free, good communication.
- High educational level and wide range of disciplines in teams.
- Motivated and knowledgeable head of research.
- Many ideas and problems originated from customer needs.
- Tests and experiments were common for solving problems.
- Ideas often originated from individuals and then were improved in a group setting.
- The technology was exciting, complex and challenging and there was an interest in understanding the problem and to do a good job.

6.1.2. Document study

The innovative projects related to photo mask writers for the display market, were early projects and thus no documents of the relevant type were found from this time. Therefore, the results for this case are fully reliant on the interview data.

6.2. The Sigma project

In this chapter, the results for the Sigma case are presented, including the interview results and the document study results.

6.2.1. Interviews

The communication in the Sigma project was direct and personal, which meant ideas and problems were often communicated between employees in workshops or meetings using white boards as support. In cases when direct conversations weren't an option, emails were used as a communication channel. There was also plenty of communication and exchange of information between the different disciplines.

The work space was open-plan, and hands-on work with the machines was part of the daily work routine. The atmosphere was positive, open and trusting. Though, the stress levels were high, but according to the interviewees this could have been both positive and negative for the innovation. They also mentioned that the negative stress in the form of tighter time plans and pressure from top management has increased over the years.

The organization and its hierarchy were described as informal, or "loose", with no set work roles. Some interviewees mentioned that the amount of time spent on administrative work has increased and that this has decreased the creativity and the time to help others. A few also mentioned that processes lower the freedom in development and that this therefore has a negative impact on innovation. According to the interviewees, top management had more trust in their employees being innovative, during this time, instead of trying to control innovation with processes. There was no structured way of working with innovation prior to the introduction of a method called “7-steps”. This was a method introduced by Mycronic’s customer Intel, and was an attempt to solve problems in a structured way. Prior to this there appears to have been no structured method to solve problems at the company.

The teams were small or larger project groups were divided into smaller groups. There was a high percentage of PhDs in the groups from a variety of different disciplinary fields. Something that was mentioned by interviewees is that there have been a lower proportion of people in the groups that had knowledge about several machines compared to earlier, which was claimed to make the work more difficult.

During this time there was a motivated and knowledgeable head of research, who was claimed to be important for the success of the project. Top management was also supportive of the project and had faith and trust in the project teams. Beyond this, there were also one or a few individuals actively working towards improving innovation, which was important according to the interviewees. There was also a competitor at this time and in this market, and it was made clear during the interviews that this was something that was thought to have been positive for the innovation.

The problems that were solved were often identified through technical demands from the technology or through problems experienced by customers. The extent to which information about these problems spread throughout the company seems to have varied between interviewees, depending on their role in the project, but it was always clear who to ask for help when needed. Ideas were generated from individuals or in meetings. There was an open and accepting environment, everyone shared their ideas or problems and there was no prestige, which was claimed to increase the quality of the ideas or the discussions regarding those ideas. This environment also meant that everyone helped each other with projects that they weren’t part of themselves. Despite this, some good ideas were scrapped either because they were difficult to protect or because they weren’t economically justifiable. These ideas were then not taken care of for later use. During the Sigma project, employees seemed to perceive the possibilities for exploring their own ideas as greater, compared to today, where stricter timekeeping is enforced. There have been some attempts later to try to replicate this with varying success.

The most frequently mentioned motivations or drivers in the project were that the technology was exciting, complex and high tech and that there was a feeling of pride from doing something good. There was also a clear vision in the project, which provided a direction and purpose. Financial compensation existed for filed patents, however this was not the most important driver for the creation of ideas, but rather important for producing the patents. According to some interviewees, this incentive system could also have contributed to people not sharing their ideas. This is because the compensation then would be split amongst everyone involved. Below is a summary of the most frequently discussed topics during these interviews;

- Communication was done face-to-face informally or in meetings and using white boards.
- Open-plan office spaces
- Positive and accepting atmosphere between colleagues, close relationships and high trust and helpfulness.
- High stress levels, which was talked about both in a negative and positive sense. More negative stress over time.
- Informal hierarchy.
- Small teams, which was considered good for innovation.
- Driving spirits or enthusiastic people were present, which was important.
- External competition existed and was motivating.
- Many ideas and problems originated from customer needs.
- Ideas often originated from individuals or from meetings.
- The technology was exciting, complex and challenging and there was an interest in understanding the problem and to do a good job.
- There was a clear vision.

6.2.2. Document study

The Sigma project was a large project, divided into roughly 20 smaller sub-projects. There appears to have been around 9 people in each team, with around 75% of the work force located in Stockholm and 25% in Gothenburg. There were also documents explaining that the Gothenburg office wasn't involved in all project related work tasks, meaning that the Gothenburg team was separated from certain activates in Täby.

Weekly meetings and a large number of local forums, for each sub-project, appear to have been the official communication channels. It was mentioned in the documents that the overall control of the whole project sometimes was difficult, but that the communication was effective within each sub-team. There also seems to have been some sort of product development process in place with tollgates, bringing a degree of structure to the work. Some other attempts to project models or systematic product development seem to have been used at later stages in the project, such as an attempt to introduce the V-model.

At this time, the market was driven by higher and higher resolution displays following Moore's law. There was also a push towards more functionality at lower cost, which meant that microchips needed smaller and smaller line widths. During the Sigma project, there were a number of different roadmaps used to keep track of technologies that were going to be introduced in the future. One roadmap showed, for example, the different generations of the SLM technology, including release dates and specifications. There was another roadmap that depicted the different, future, versions of Sigma on a timeline. Additionally, there was a clear goal or vision which was "To establish Micronic as a major manufacturer of semiconductor mask writers".

Problems were often found through different observations, e.g. using microscopes to analyze the photo masks produced by the machines in the lab. Mycronic also seemed to have continued close collaborations with the University in Germany, when they worked on and improved the SLM technology, meaning the company had close collaborations with external partners.

Regarding knowledge management, Mycronic seems to have made efforts to reuse knowledge and to draw upon existing expertise within the company. Documentation was also encouraged and project teams were supposed to write project reviews of their experiences. They also stressed the fact that documentation work shouldn't distract people from their current projects, hinting that people complained about to much administrative work.

6.3. The ejector project

This chapter presents the interview and document study results for the ejector case.

6.3.1. Interviews

In the ejector project, the communication was direct and informal. Meetings, as well as digital notice boards and databases for discussions, were used as a means for communication. Communication between the different disciplines also existed. During the interviews it was also mentioned that it was easier to communicate since the company had fewer employees and that there was less bureaucracy.

The work place had an open-plan office space and a significant part of the time was spent in the lab working with the machines. The working atmosphere was positive and everyone was open and supportive with one another. There was also a forgiving attitude towards mistakes, which according to some interviewees was important. The interviewees claimed that the experienced stress levels varied a bit depending on which part of the company this person was working in and how well this person could handle stress. Though, there were strict time schedules to follow at the time.

There was a hierarchy, though it was informal and loose. The different roles or responsibilities were a bit fluent and overlapping. The CEO was also much more closely involved with the problems and the development work and there was a better consensus on what was important and in what direction the company should go, compared to today.

The teams were small with less than 10 people from different backgrounds, both educational levels and disciplines. Some interviewees also mentioned that they had people with different personalities in the teams as well and that this was important. The teams were, to some extent, autonomous which gave them a certain level of authority over decision making, resulting in faster decisions. With fewer employees with was also reportedly easier to make decisions at a company level. At this time, there were also more people with system knowledge, which was reported to increase problem understanding in general.

During these projects, there were good leaders who took responsibility and had great technical knowledge. Management was also supportive of the projects, which according to the interviewees was important for innovation.

There has always existed some level of external competition, but the competition has increased over the years as this line of business has matured. Earlier, the competition was more related to the function of the products whereas the cost has become more important over the years. External competition was described as having a positive effect on innovation since it provided a motivation for improving the products.

Ideas arose through human interactions or through individual work. These ideas often came from individuals and were then discussed and improved in a group and there was no prestige. The problems came from customers or from technical demands. There was also a closer interaction with the customers at this time, which lead to a better understanding of the problems, which fostered new ideas, according to the interviewees. The interviewees also mentioned that they believe curious individuals are important for innovation and that it's important to have time for practical work with the machines in the lab. There were times when good ideas were not pursued and this was mainly because of time or financial constraints, but also cases where leaders suppressed someone's ideas. Another aspect that came up during the interviews was that it not always was the same person who identified the problem, who then solved it, sometimes an expert was needed. The problems that were identified were also more easily spread throughout the company when the company was small. It also seems to have been easier to work with ideas outside of the current project, compared to today, since the organizational structure was more informal. Having time to work on these ideas was something that the interviewees mentioned as positive and important for innovation. Some interviewees mentioned that ideas that solved the immediate problems or that posed a clear opportunity for improvement were more likely to be acknowledged.

The motivations and drivers were mostly that the technology was exciting, interesting and fun and some interviewees mentioned that technologically advanced tasks were preferred over cost reductions of the product. Others stated that projects, which included opportunities and close customer interactions, were preferred over solving problems or faults in the machines. People also felt that they had a relationship with the product and they wanted it to succeed and make the customers happy. Another motivation for making the customers happy was that the employees had met the customers in person and felt obligated and willing to help them. The interviewees also stated that there was a feeling of contribution to the cause and that everyone worked toward a common goal, which was motivating.

Below is a summary of the most frequent topics of discussion during these interviews;

- Communication was done face-to-face informally or in meetings.
- Worked closely with the machines in the lab.
- Positive and accepting atmosphere between colleagues, close relationships and high trust and helpfulness.
- High stress levels for some individuals.
- Informal hierarchy.
- Worked closer to the CEO, which led to higher consensus on what was important and in what direction to move.
- Small teams
- People with different backgrounds, education levels and areas of expertise in the teams.
- Top management was supportive of the project and there were great leaders who took responsibility.
- External competition was present, which was considered motivating.
- Human interactions or individual work tasks often led to new ideas in individuals that were then discussed in a group.
- Many ideas and problems originated from customer needs and from technical demands.
- Had closer interactions with customers, which contributed to a better a understanding of the problem and to new ideas.
- Curious individuals, who were considered important for innovation.
- The technology was exciting, complex and challenging and there was an interest in understanding the problem and to do a good job.

6.3.2. Document study

This document study was entirely based on a large discussion forum used by MYDATA, before merging with Micronic Laser Systems to become Mycronic. This forum was frequently used during the development of the ejector technology and was described as an informal communication channel where members could freely start discussions regarding any relevant topic. The information stored in this forum is vast and considered a company secret, and thus only an investigation to discern general patterns could be made. However, due to the nature of this forum it was considered to be highly relevant for this thesis.

Upon entering the discussion forum there are clear instructions describing the intent of the forum and how it was supposed to be used. The forum appears to be open to everyone involved in these projects and most of the posts appear to be informal in nature. The forum is structured around general topics regarding various components of the machine and around the different teams who partook in the project. These topics are of the nature “general discussion about the ejector” which, judging by the massive amount of created posts under each topic, appears to have created an environment where it was free to discuss problems, ideas and, raise concerns. This forum is no longer actively used to communicate and rather serves as a database where an incredible amount of knowledge is stored.

During this time, the projects were divided into several smaller teams of 5-8 participants, where each team had different areas of responsibility. Problems and ideas for improvement were openly shared on the forum and positive feedback was frequently observed. Documents were found which celebrated certain accomplishments, and several PowerPoint presentations conveyed a sense of friendliness, containing jokes and words of encouragement. There were also documents pertaining to workshops aimed at solving problems discussed on this forum. A workshop in particular gathered members of the projects and divided them into smaller groups. Each team then brainstormed solutions to a specific problem and later presented their solution to the rest of the teams. The solution was then prioritized based on how easy it could be tested, where a quick and easy test was preferred over a more time-consuming test, and based on the impact of the solution to the problem. There was also a document discussing discarded ideas (although the reason why was not specified) and the possibility to examine these ideas for future use. Another description of a workshop was found with the aim of compiling all of the teams' current knowledge regarding the ejector, identifying gaps in this knowledge and subsequently closing these gaps. This workshop also had the aim of establishing a consensus for design. Beyond this, documents encouraging the increase of documentation regarding performed tests in the project were found. The documentation was instructed to include; a description of the problem, conclusion and analysis, the test setup along with samples, and instruction to upload this information onto the discussion forum.

A project experience review from a project completed in 2009, detailing positive and negative aspects of this particular project, was found. The relevant topics for this thesis include:

- The Pulse meeting methodology (stand-up meeting using visual aids) was an effective project management model, where priorities and project steering worked well. Crisis groups were also used to effectively solve problems.
- The project scope became too large over a long period of time which made it difficult to maintain focus.
- Lack of attempts to increase motivation and lack of opportunities for team building.
- Employees raised concerns regarding the attempt to force research into a project which has a limited time frame.
- The project leader was replaced half way through the project which was considered unfavorable.
- The team members felt that there was insufficient documentation detailing conclusions of the tests that were performed during this project.
- The team members expressed a need for an easier way to locate relevant information in the future.
- Cooperation between the teams responsible for software was lacking and no one took responsibility for this.
- The team expressed that the project had a solid foundation through a well performed pre-study, with large width.
- The team had project procurement managers, which were considered effective and helpful in the project.

6.4. Rosetta/Gamer and Laser Direct Imaging

The Rosetta/Gamer and LDI case results have been gathered in this part of the report. First, the results from the interviews are presented and thereafter the document study results.

6.4.1. Interviews

The preferred communication method in these projects was reported to be direct communication between people, preferably in front of a white board. The LDI project reportedly had a good communication between disciplines, which was considered a positive factor that contributed to innovation in this project, since it provided different approaches to solving the problems. Email and the case management software Jira were also common communication channels.

An open-plan office space was used during these projects. The relationship between colleagues was describes as open, accepting and overall good. Colleagues were always quick to help each other across projects or when a problem arose. However, some interviewees reported that during the LDI project, the time for this was limited. Every interviewee mentioned that the stress levels were high. The stress levels in this project were described as more negative compared to stress experienced in earlier projects they had been part of. There were reports of unrealistic time plans that wore people down, or stress caused by having to do administrative work rather than tasks that the interviewees were hired to perform. These comments were only related to the LDI project with the Rosetta project having high stress levels with no mention of these problems. However, one interviewee mentioned that there was a lack of commitment from the rest of the company towards Rosetta, which was a company initiative rather than a customer driven project.

The organizational structure was described as an informal or "loose" hierarchy, with no defined work roles, which was considered positive. These projects followed a project-based model. One interviewee mentioned that more innovation had followed from having a more product-based approach compared to following a predetermined project template or model, at least in the software department. The team working with software development preferred to meet, away from the office, and work undisturbed with the problem at hand. Several interviewees mentioned that the amount of processes have been increasing which they felt was restricting and reduced innovation. Rosetta had a supportive management with a clear vision while the reports regarding management's involvement in LDI are more conflicted. One interviewee reported clear leadership roles during the LDI project while the rest felt the leadership was lacking. No project leader or manager appeared to take responsible for making sure the project was moving forward. This was instead placed on individuals working with technical implementation, resulting in more administrative work and reduced creativity.

The LDI project was divided into smaller groups and Rosetta was a smaller project with around 15 people. These projects both had a large number of PhDs and engineers. One interviewee with a long history working for Mycronic felt that there were less people with broad knowledge of their product than before, which slowed down the work on the new machine being developed during the LDI project. All interviewees reported that external competition motivated work during the LDI project.

Ideas were reported to initially arise from individuals and then to be improved during group discussions. Many interviewees noted that there needs to be an absence of prestige or barriers, physical or otherwise, for people to share their ideas, with several interviewees mentioning that sharing ideas was both common and rewarding during these projects. Ideas arose from working with problems, described as having a problem-solving culture. These problems came primarily from customers and their needs as well as from problems with the technical aspects of the machine. However, Rosetta was a company-initiated project, which was driven by internal problems rather than customer problems. Rosetta was also an entirely new concept or a "blank slate" and the people working in this project felt this provided a greater freedom to create. The identified problem was reported to be well known within the team during the Rosetta project. During the LDI project the identified problems were well known within some teams and in other cased limited. The identified problems appeared to be solved by the same individuals who identified them, if they had knowledge about that part of the system, otherwise an expert could be needed. The problems were also commonly identified by people working with integration and then solved by experts in the area relating to that specific problem.

Many interviewees reported that the time for exploring alternative solutions or own idea was limited during these projects compared to previous projects. A frequently mentioned explanation for this was that there was more follow-up and administrative work during these projects. However, a few interviewees reported that there have been attempts to allow more time to explore personal ideas but that this did not work in practice.

Each interviewee felt that they were making something unique and working with interesting technology. They also felt that solving complex tasks and problems was something that was motivating. Economical compensation for writing a patent existed and was considered helpful for investing time into an idea. However, several interviewees mentioned that this wasn't something that motivated them and the software department does for instance not focus on patenting. Innovation in software was described by one interviewee as "finding the best algorithm for a certain application". Below is a summary of the most frequent topics of discussion during these interviews;

- Communication was done face-to-face informally, often using white boards.
- Open-plan office space.
- Positive and accepting atmosphere between colleagues, close relationships and high trust and helpfulness.
- High stress levels
- Informal hierarchy.
- Small teams, with high percentage of PhDs and engineers.
- External competition was considered motivating and was present in LDI, but not in Rosetta.
- Ideas often originated from individuals and were then discussed in a group.
- Many ideas and problems originated from customer needs or from technical demands.
- There was financial compensation for patents, but this was not considered important.
- The technology was exciting, complex and challenging and there was an interest in understanding the problem and to do a good job.
- Clear vision in Rosetta.

6.4.2. Document study

The document study helped to support many of the findings from the interview sessions. The Rosetta project appeared to have had a total of 11 members and by searching the team members' names in the company database it could be established that they had varying disciplinary backgrounds.

The Rosetta project was described as an entirely new platform attempting to unify all current data platforms used in Mycronic's existing products as well as in possible future products. This appeared to be thought of as a complex and technically difficult challenge, with nothing of the likes being undertaken previously by the company. The requirements placed on this new architecture appeared to be mostly coming from internal needs, such as the needs of the existing data platform and the need to make Rosetta viable for 10 years. However, customer demands were sometimes mentioned, such as varying writing speed, which placed certain demands on the data path. To support this technically challenging project, Rosetta was well prepared with a solid foundation in the form of master theses, software toolboxes and hardware toolboxes. These toolboxes had been prepared beforehand to assist the development processes, by providing relevant and important information related to the different application elements.

The Gamer project was described as a strictly technical project where questions regarding business considerations or life cycle compatibility were expected to be handled by other parts of the organization. This project also used a lot of gaming related metaphors associated with different subprojects. Since Gamer would be almost as high performing as a super computer, this was used as a metaphor for the whole project. This analogy of building a super computer persisted throughout the project and appeared to convey a purpose for the design. Gamer was also considered a learning project for Mycronic to increase their understanding of acceleratory technology (GPU) and OpenGL. There were also documents indicating use of visual planning boards and "Pulse" meetings. Additionally, there were mentions of functionality and features being postponed due to low demand. There was also a lack of funds for completing wanted activates during the Gamer project.

Both the Rosetta and Gamer projects had some go/no-go gates that the projects had to pass to continue. The team members in these projects also felt that they had plenty of time for these projects, when they initially started. However, the projects ended up being late and the team had a lot of work to do in a short amount of time, a quote from the Gamer project stated "We are several weeks behind". There was also a significant increase in project costs from what was originally estimated. However, the scope vastly changed from proof of concept implementations in a Data Path to a complete Data Path that could be used in a real system. The scope and quality level of the developed applications had increased. These projects were also only financed using own R&D funding, and not through other means. According to some of the project objectives, the results from the projects were considered most important, then time was considered second most important and lastly, cost was considered least important. The document study further revealed complaints toward a low performance solution being implemented in last minute, due to time constraints. This decision resulted in rework of the code afterwards to get rid of the bottlenecks and to increase the performance.

During the implementation of Gamer into the LDI project, tests and experiments with the machine appeared to be common. The subsequent problem was communicated through PowerPoint to the rest of the team. Customer demands also appeared to play a larger role during this implementation compared to the Rosetta project.

An after-project report was found detailing lessons learned related to Gamer's part in the industrialization phase of the LDI project. This was the only document found of this kind and it highlighted many positive and negative aspect of this project. The relevant, positive topic for this thesis includes:

- Knowledgeable employees made it easier to work during uncertain conditions
- Dedicated test environment made it possible to evaluate both hardware and software
- The Scrum method was reported to work well
- Geographical closeness between chief architects and the developers was considered important
- There was openness between colleagues

The negative aspects regarding this project were reported as:

- Parts of the team not co-located
- A lack of use-case priority
- No one took responsibility for approving implementation of new functionality or corrections
- No established rules for writing code or they were simply not being followed
- Many changes of the interface close to the release date
- The test facilities were inadequate and not collocated with the team
- Lack of informal meetings and participations on other team members' demos
- It was reported that a group from another part of the LDI project was relocating people away from this project which was not appreciated
- It was reported to be reduced information sharing after a change in the Scrum groups

6.5. Summary of the case study

The results for the interview phase of the case study presented several distinct similarities between the different projects in terms of potential innovation mechanisms, both positive and negative. The similar, positive, factors from the studied cases were:

- Communication was mostly done face-to-face, informally.
- Interdisciplinary communication was common.
- Positive and accepting atmosphere between colleagues, close relationships and high trust and helpfulness.
- High stress levels for some individuals, often talked about in a positive sense.
- Informal hierarchy without clearly defined roles for individual employees.
- Small teams, with different backgrounds and often a high educational level.
- External competition was mostly present, which was considered motivating.
- Ideas often originated from individuals and were then improved during a group discussion.
- Many ideas and problems originated from customer needs or from technical demands.
- Close interactions with customers, which contributed to a better a problem understanding and fostered innovation.
- Responsible and enthusiastic leaders or colleagues who created an innovation culture.
- The technology was exciting, complex and challenging and there was an interest in understanding the problem and to do a good job.
- Always had a vision or a common goal.
- Fewer processes, which was considered good for innovation.
- Worked closely with the machines in the lab and performed tests and experiments.
- Ideas need time to be tested and explored

A frequently mentioned part of Mycronic's history was the office in Gothenburg. This was described as an important drive for innovation in the company. The Gothenburg group was described as consisting of individuals with great technical knowledge and understanding of both customers and the products. This group's success was often attributed to these individuals, but also the fact that this group was separated from the daily activates which took place in Täby. Instead of worrying about delivering the machines, they could spend more time thinking about and exploring ideas and alterative solutions. Many interviewees felt that a large part of the company's innovation culture was lost when this office closed, and thus a decrease in innovation rate followed.

The factors which had affected innovation in a negative sense appeared to increase as interviewees discussed more recent projects. This was especially noticeable from interviewees who had stayed with the company for a long period of time. The administrative work placed on each individual, especially experienced individuals, appears to have increased, even thought this was not necessarily part of this person's job. This was reported to cause a higher stress level, with work being piled up on their already busy schedule. The administrative work appears to have increased in general, however this increase was sometimes credited to a lack of leadership in the projects. The lack of leadership meant that no one was taking responsibility, which resulted in more administrative work being pushed onto employees who were working with solving technical problems. This reduced both time and motivation to solve technical problems. Many interviews also reported an increase in various types of processes aimed at controlling the development effort. This was described as having a dampening effect on innovation, or provided a strict way of working with little room for innovation.

It was made clear during the interview process that, both problems and ideas, originated from direct customer contact. However, it was reported that, with the growth of the company, fewer employees were exposed to customers, which in turn have led to employees having a decreased understanding of both the customer and their problems. This customer contact was described as important for understanding the problem, and thus for inventing something the customer actually needs. A significant part which drove innovation forward could be identified as the challenge and recognition of solving a difficult problem; however the opposite of this, that of seeing one's idea ignored or placed on a “list”, was described as negative for innovation. This could create a sense of bitterness or a mindset where sharing ideas seemed pointless since nothing happened with these ideas.

The document study supported many of the findings from the interview process, especially topics that were naturally documentable such as team sizes, team composition and time schedules. The document study also provided an insight in how the company communicated or distributed information during these projects, which appeared to be mostly through meetings using PowerPoint or discussion forums. There appears to have been a gradual shift towards using the Pulse meeting methodology, however meetings using PowerPoint have remained common.

As with the interviews, several similarities between each project could be found. These are presented below:

- Small teams.
- Communication through meetings, often with PowerPoint.
- Workshops.
- Clear vision or common goal.
- Visual communication: Roadmaps, metaphors.
- Tests and experiments were considered good. However sufficient time needs to be dedicated to this.
- Customer demands influenced development.
- Documentation was encouraged throughout the projects.
- Used different project management methodologies (V-model, Pulse meetings, Scrum)
- Solid foundation in the form of pre-studies.
- Lack of resources for completing wanted activities, which sometimes lead to usage of underperforming solutions.
- Important with leaders who take responsibility and motivate the team.
- Important with informal meetings and teambuilding.
- There was openness between colleagues.
- Important to maintain group integrity throughout entire project.
- Important with co-location, regarding both team members and managers.

There was no structure or standard established for how to preserve knowledge and information in the studied cases. There was a file naming scheme used to organize the projects stored on the various file servers in a chronological order. However, once a specific project was located, each project appeared to use (or not use) a file structure established for that specific project. There were no similarities between how different projects stored files, or even what type of information that was stored. For instance, “project documentation” could mean a detailed technical report in one project, and meeting notes in another project. This inconsistency made it impossible to establish a systematic way of identifying relevant documents. However, several relevant documents and search paths on servers could be identified by asking employees at the company. A common approach for finding relevant documentation was to email an employee which had participated in the project in question, this employee would then point to a folder on a server or provide contact information to another employee who could help. The document study revealed that finding relevant documents could be a concern, this was especially a concern raised by the ejector group.

The documents stored on four of the five data sources appear to not be maintained or updated anymore, the exception being Confluence. This observation was strengthened by the fact that there were several empty folders, corrupt documents, instructions for path ways that no longer exist and, cases where the same information was posted in several locations. Many pathways, such as folders, were named using abbreviations or what appears to be a “personal file naming scheme” which further complicated the search for relevant information.

6.5.1. Knowledge Management

The knowledge generated during the studied cases was reported by the interviewees to be preserved within individuals who were working on the projects at that time, which is true for all the studied cases. This knowledge has mainly been stored and reused by employees who have worked in the company for a long time. The interviewees also frequently mentioned that innovative and knowledgeable individuals have now left the company, people have retired or moved on to different companies for instance, taking their knowledge with them. However, documents have always been stored in various databases; these documents appear to be stored in different databases depending on where in the company and when these documents were created. These documents were reported to contain, for instance; product descripting and data, summaries of the projects, and code. There were also reports of methods being implemented during later projects to promote documentation, such as the A3 method, Lean concept descriptions or the V-model. Several interviewees reported that this encouragement did not work as intended and instead felt like a chore, requiring even more administrative work, or restricting the work too much to capture what was important. The remaining interviewees felt there was no official incentive to capture and store knowledge at all. Finding information in these databases was frequently reported to be difficult since there appears to have been no standard structure for storing the information between projects and a lack of searchability. Most interviewees reported that the most efficient way to extract knowledge related to older projects was (and is) to directly ask a colleague, who was part of the project in question. Searching the database Confluence was also mentioned as a way of extracting information or, to ask a colleague who was part of the project, in which database the information could be found. Larger or more radical innovations were described by one interviewee to be more thoroughly documented and accessible compared to incremental improvements. The documentation regarding the incremental improvements tended to be discarded. Another interviewee mentioned that there was no point in storing this in a database since it seldom would be used again, or that this knowledge sometimes was stored for personal use only.

7. Analysis

The similarities between the studied cases are of special interest since these represent potential innovation mechanisms that have persisted through time, and could therefore have been a large part of the innovative culture during these projects.

During the earliest of studied projects, the company was a small local business in a startup or expansion phase. Several of the changes experienced by the interviewees can perhaps be attributed to the fact that, Mycronic no longer is a small local company. The innovative environment during this time can at least partially be explained with the theoretical framework regarding innovation in smaller companies. The interviewees reported that the organizational structure was informal, even more so during the early days of the company. They described it as, managers and decision makers being either directly involved in the projects, or easily accessible. This led to a highly adaptable organization that could make quick decisions regarding the direction of the development. What the interviewees described, has several characteristics of an organic organizational structure, which is an organizational structure that is known to foster creativity. It is therefore reasonable that the informal hierarchy the interviewees described could have been a major innovation mechanism. However, the drawback of this organizational structure is that it is worse at achieving a high operational efficiency and reliability. With the growth of the company it's also reasonable that a more mechanistic organizational structure has been adopted since it allows for a higher operational efficiency when managing a large company. However, this organizational structure could stifle innovation. Since this informal organizational structure was reported for all the studied projects, it could be beneficial to retain an organic organizational structure, at least during project phases where a high level of creativity is needed. The question of organizational structure is a complicated issue which probably requires a more in-depth investigation than is possible within this thesis. However, what the interviewees described as an informal organizational structure was identified as an innovation mechanism. The executives or leaders during this time also played an important role in creating an open and trusting environment. Beyond taking responsibility for managing the company, these people were often described as possessing great technical knowledge of the company's products. Having the ability to both manage the company and maintaining a technical understanding of their products was perhaps possible because there were fewer people to manage. As a company grows and starts to have a global presence, it is natural and necessary for changes to the organizational structure to occur. It requires more administrative work and formal communication channels to manage a project consisting of 300 people, spread out across the world, compared to a project consisting of 30 people working in the same building. The employees also appear to not have any specific roles or titles; instead the employees had areas of responsibility. This way of working appears to have allowed employees to experience different components of the highly complex machine being developed. This could in turn have contributed towards developing a system knowledge, which some interviewees described as helpful for performing tests and communicating across disciplines. Most interviewees reported that ideas often originated from customer needs, both expressed by the customers themselves and observed by employees working close with the customers. This signifies the importance, from an innovation perspective, for exposing employees to customers and their problems. During these early projects, the size of the company could have made exposure to customers more frequent for employees. The employees could meet with customers themselves, or the size of the company would increase the chance of discussing problems with colleagues who were in contact with customers. It would not be possible for all employees in a large organization to work closely with customers to the same extent, and a different approach with more active customer information sharing would have to be used. The informal organization in combination with trusting leaders also appears to have created the possibility to, or at least an acceptance, to both work on own ideas outside the commercial project, and to help colleagues. This was also aided by the general product-focused development at this time, which meant that everyone worked together to solve individuals' immediate critical problems that threatened delivery. Even though Mycronic no longer is a small company, actions could still be taken to stimulate innovation based on success factors from this time, which is what the proposed framework needs to accomplish.

The concept of using small teams has always been practiced in the company, presumably because of the benefits this gives regarding communication and team spirit. In small teams, it's easier to discuss problems and ideas, and make decisions. The environment was also described as open and trusting, which perhaps could be credited to the smaller team sizes and enthusiastic leaders who promoted innovation. A trusting environment within the team makes employees more likely to share idea since they know this will be encouraged. Teams including members with different knowledge background resulted in a larger solution space and thus a larger potential for innovation.

Spontaneous discussions or meetings were common and played a part in the innovation process at Mycronic. These meetings allowed employees to share problems and ideas with other colleagues. It's important to recognize that these meetings, often coffee breaks and informal dialogues, are not a waste of valuable work time, but in fact a knowledge sharing opportunity for employees which should be encouraged.

An interesting contradiction which was discovered during the interviews was that of limited resources, especially time. A lack of time was both described as a motivation for innovation, since it created a sense of urgency, and a barrier since ideas require time to be evaluated and developed. Not having enough time to explore own ideas, or properly evaluate different solutions to a problem, was seen by most interviewees as overall negative for innovation. However, time pressure or lack of funding could produce a sense of urgency which would inspire smarter solutions to compensate for a lack of resources. Time pressure could also force communication to bypass official hierarchal communication pathways in favor of a quick and informal communication pathway, which usually is faster compared to official channels. The framework therefore needs to reflect resources, especially time, as a motivation which could inspire novel solutions while at the same time realizing that turning an idea into innovation requires sufficient time. The time needed may vary depending on the problem or idea at hand, however time is always needed, and allowing employees the time to explore own ideas, have in the past led to innovation at Mycronic.

The time pressure described above produced high stress levels in employees. However, the interviewees who experienced stress during these projects often described it in a positive sense, or at least were unbothered by it. This could perhaps be explained by the fact that the employees felt a great motivation and satisfaction when working with challenging technological problems. The recognition for then solving these problems, by colleagues, managers and customers, was also described as a great motivator. The experienced stress appears to have shifted towards having a more negative impact during the more recent projects. This appears to have been caused by an increase of administrative work, which was described by one interviewee as the "paperfication of Mycronic". The stress from the added administrative work decreased both time and motivation to solve technical problems. This problem has increase over time, making it difficult to pinpoint the exact sources; however a common denominator for this increase was describes as a lack of leadership. If no leader takes responsibility for the planning the project, it instead falls onto individuals working with technical problems. Having this responsibility on top of their already busy schedules led to high stress levels. The extra responsibilities appear to have been placed especially on employees who have been with the company for a long time. This is perhaps natural since these employees would have a greater understanding of the working of the company and could therefore better predict the time and resources needed for certain activates within the development. However, these individuals often possess great technical knowledge, and doing administrative work will limit the time for which this knowledge could be applied to solve technical problems. Reduced time for working with technical problems could also have removed the motivation associated with this challenge, and thus the factor which made the, often high stress levels, bearable. It is therefore important that project leaders (or other leader roles) acknowledge these individuals' strengths and that these responsibilities are shifted away from people who are proficient at working with technical problems. Many interviewees also described leaders as responsible for cultivating an innovation culture within the company, further indication the importance of leadership for the innovation process. Additionally, there was a clear corporate vision in the company, which was maintained by leaders. Visions were not only present in the form of a corporate statement, but through metaphors and analogies in different projects and in the form of e.g. roadmaps that showed long term goals of the company. These visions also helped foster innovation and were part of the innovation culture by providing clear goals and directions.

A varying degree of external competition appears to have always been present during the studied projects. The external competition was described as motivating since it produced a need to continuously improve to stay competitive. However, the opposite situation, that of being market leader existed (and still does) for the manufacturing of photo mask writers for the display manufacturing industry. This market position can reduce innovation since it lacks competition, and thus the need to improve the product in order to stay relevant in the market. The monopolistic market position appears not to have affected innovation in a negative sense at Mycronic, perhaps due to the fact that this was the company's primary source of income. This provided an economic incentive to continuously improve the product to retain a leading market position.

During Mycronic's establishment on the display market, every increase in performance of the machine was attractive to the customer. A machine with higher performance meant that customers could produce more advanced displays, which provided them with a competitive advantage. This meant that an increase in performance offered a large monetary gain for Mycronic, since one machine sold for several million dollars. This created an environment where new ideas, which could potentially improve performance, were promoted. This further highlights the importance of motivation for innovation, which for Mycronic consisted of a sense of urgency, challenging technical problems, monetary gain and recognition from colleagues, managers and customers.

The Gothenburg office was a topic that was often discussed during interviews, and it was described as a large part of the innovation culture. The group in Gothenburg was described as consisting of highly knowledgeable individuals, who had a great understanding of the technology used in the product, and of the market. This technological knowledge gave this team the ability to guide the development through clearly defined problem descriptions. The geographical distance between these two offices separated the Gothenburg group from the daily work of producing and delivering a product to the customers, which happened in Täby.

This separation allowed the Gothenburg group a great deal of time to think and explore problems and possible solutions. This also appears to have separated the group from the organizational structure of the main company, and thus allowing this group to form their own organizational structure, one that better suited their work procedures. The Gothenburg team bore a large resemblance to an autonomous development team. This team's impact on both innovation and innovation culture was immense and is therefore likely to have been a major innovation mechanism which needs to be reflected in the framework. An autonomous team is suitable for breakthrough projects or new platform projects, which e.g. the Sigma project was. It is also important to note that the Gothenburg team existed before the creation of the Sigma concept, which means that an autonomous team was not assembled for the sole purpose of developing a new platform, rather, the Sigma project, was an idea from this team. This could further indicate the importance of both trusting and allowing curious individuals the time to explore ideas.

Processes aimed at controlling the work flow was a controversial topic for many interviewees. The innovations at Mycronic were never credited as a result of following a certain development process. Instead interviewees claimed that innovation always has been the result of individuals working with problems. The nature of many processes, which is to provide a direction for the development and ensure that the work progresses, was described as a limitation for innovation. Where innovation requires freedom of exploration and time, processes try to increase efficiency, which often comes at an expense of what the interviewees felt they needed for effective problem solving. However, this does not mean that a process which is designed with innovation in mind is unbeneficial, just that the process experienced by the interviewees wasn't aimed at innovation, and thus counteracted it.

Judging by the state of the information stored on the various servers studied during the document study, it could be determined that this information and knowledge was not intended for easy reuse, but rather as a long-term storage of old project documentations. This observation is further supported by the lack of general maintenance of the documents stored on the servers. However, there were documents that had been maintained and updated, though for many documents, the opposite appeared to be true. To give an example, an "after project review" was found, which could be considered an important attempt to improve future projects. Though, the document contained spelling mistakes and no attempt to explain the feedback provided. This could indicate that this document was hastily made, stored on the server, and then forgotten, with none of its lessons and suggestions used in future projects. There were also files, such as pictures, stored on these servers which could be considered not work related. These files (although sometime amusing) made it even more difficult to locate relevant information. This could also indicate that these servers sometimes were used as thoughtless storage for everything going on at the time, work related or not. The number of databases complicated the search even further since a project, depending on the length and the size of the project, could be spread out over multiple databases, shared work spaces, or forums.

The structured attempt that was made to codify knowledge and lessons learnt, which was talked about during the interviews, and later found traces of during the document study, appears not to have been reused to any great extent. It was more common for this knowledge to exist within the individuals who partook in these projects. This was especially true the further back in the history one looked, with no documentation being found for the earliest photo mask writers. It was also favored to ask these knowledgeable individuals for help whenever knowledge from earlier projects was needed, compared to consulting the various data bases. This was described as the best source for extracting knowledge and worked well as long as these individuals were still in the company. However, with the closing of the Gothenburg office and the retirement of many of the employees from this time meant that much of their knowledge was lost. The loss of the knowledge related to the closing of the Gothenburg office could also magnified due to the geographical distance from Täby. Since the group in Gothenburg was isolated from the daily work in Täby it could mean that tacit knowledge developed at Gothenburg was not transferred to Täby, since this type of knowledge is mostly transferred through personal contact and observation. Even though the geographical distance appears to have been a success factor in term of innovation it could have been a barrier towards knowledge reuse. The loss of these knowledgeable individuals, and part of the knowledge could perhaps, in part, explain the lost innovation culture explained by several interviewees.

8. Innovation framework

The result of the case study highlighted different innovation mechanisms which could have affected innovation during these earlier projects. These mechanisms, both positive and negative, were then used to create a framework which can be used to foster innovation in future development efforts. The framework describes the innovation environment that permeated the organization during the studied projects.

For the sake of generalizing the framework and extending its applicability beyond specific projects at Mycronic, the framework was created using key innovation mechanisms which where common between all of the studied projects. The individual project’s success factors proved, with some exceptions, to be generally the same or at least similar in nature. The success factors which could be identified between the projects was relating to the following topics:

- Team composition
- Communication
- Problems and ideas
- Work environment
- Organizational structure
- Leadership
- Motivation
- Vision

Team composition

Using small teams, with a maximum of 10 members, was identified as a success factor because it resulted in efficient communication and tightly knitted groups who worked well together. This is because everyone in the teams got the chance to get to know one another, including their strengths and weaknesses, which created trust within the group. These teams worked most efficiently, in a problem-solving capacity, when the knowledge background in the teams was broad. This made it possible to approach a problem from multiple angles, and thus improving the overall performance of the solution. It is therefore recommended to have, when possible, at least one person from each relevant discipline in the teams. Individuals with system knowledge also play a critical part of each team and the innovation culture, since these individuals are important for communication between disciplines, making testing and exploration of ideas easier as well as for improving customer and problem understanding. Moreover, it’s important for the team to be collocated so that communication is as efficient as possible and to increase the chance for spontaneous meetings, which both are important from an innovation perspective. All team members should also remain in the project for its full duration, to avoid unnecessary obstructions to the development work.

Communication

The richest type of information exchange between individuals is that of face-to face communication. This type of communication was also derived as a success factor for an innovative environment, during the studied projects. An important type of face-to-face communication is that of spontaneous meetings between colleagues, which should be encouraged by for example, as discussed earlier, having co-located teams, or by creating a natural meeting place (White boards being a favorite for Mycronic). Increasing the chance of spontaneous meetings is beneficial since it provides a natural way for sharing and discussing problems and ideas with colleagues. Barriers which restrict this type of communication should therefore be avoided. These barriers could include geographical distance or locked doors. Further, communication which is unrestricted by the hierarchy of the company is more effective. It is therefore important to avoid hierarchical pathways as much as possible, especially if time is a critical constraint. In the larger company, official and hierarchical communication is necessary to manage the company, however it could still be valuable for innovation to limit this as much as possible within the team. In addition to encouraging spontaneous meetings, planned meetings also appear to have been a preferred way of communicating problems or customer needs. The continuous use of the Pulse methodology and team meetings, using aids such as Power Point, is therefore also suggested to be retained.

Problems and ideas

Most interviewees agreed that ideas arose when working with a problem. The problems came mostly from customer needs, both expressed needs and potential needs observed by employees. Since most problems and ideas have originated from customers it's important to expose the members of the team to customers. Understanding the context of the problem or how customers use the product will increase the chance of creating something that is of value to the customer. For these reasons it is important that each team member understands the customer and their problems. This could be done, if possible, with customer visits by the entire team. Perhaps a more realistic approach would be to have dedicated team members, representing more than one discipline, who meet with the customers. These team members will then present important findings from these visits to the entire team.

Many innovations have originated from individual work performed outside of the commercial project. The interviewees felt that the time for exploring own ideas have diminished over time, and given the success of having this time in the past, this is something that should be encouraged. Attempts to dedicate time and resources for exploring own ideas have been made, which most interviewees agreed was something positive for innovation, indicating this should be further encouraged. This could be done by trusting employees and allowing the dedication of resources for the exploration of ideas, on the employees' own terms. Ideas were sometimes discarded due to time-constraints or financial constraints, which further suggests that enough resources should be allocated for exploring and testing of ideas.

Ideas originated within individuals and were often improved by sharing and discussing the idea with colleagues, some interviewees even saw the sharing of ideas with colleagues as a natural step of the innovation process. Since idea sharing often was seen as a natural part of innovation at Mycronic it could be beneficial to both encourage this and allow time for group discussions of ideas and problems during projects. During these discussions it's important that a leader both encourages and creates a safe environment for individuals to contribute. Sharing of ideas could also be promoted by encouraging more spontaneous meetings, or through dedicated sessions, such as team meetings and workshops.

Work environment

Sharing ideas with a group could, as previously mentioned, improve the idea, though this requires a certain environment where this is appreciated and encouraged, and where mistakes aren't punished. The environment needs to be trusting, open and prestigeless, for ideas to be shared freely. However, there were indications of ideas being shut down during group discussions which was detrimental for innovation in these cases, further advocating an open and uplifting environment. There was also an agreement among the interviewees that the will to help others always has existed, yet the time for this has been limited, especially during more recent projects. Another action to improve innovation could therefore be to allow employees more time to help each other across project boundaries, and to see this as a benefit for the entire organization.

High stress levels appear to have existed throughout all the studied projects. The stress levels during the early development of mask writers for display manufacturing were mostly described as positive. The high stress in these projects was attributed to strict delivery dates and limited resources. The limitation in time and resources could serve as source of motivation since it created a sense of urgency which in turn fostered the innovation of smart solutions to overcome these limitations. The higher stress levels were also acceptable since employees felt that working with challenging and technical problems was rewarding. The high stress levels started to become a problem when the workload shifted towards doing more administrative work on top of working with technical problems. It is therefore important to reduce the amount of administrative work placed on these employees, allowing employees to focus on the technical problems. This responsibility could instead be placed on a project leader. A high stress level could therefore be a motivation for innovation if the employees feel like they are working on a value adding challenge; otherwise this stress becomes a burden and can result in burn outs.

Organizational structure

The informal organizational structure, discussed during the previous chapter, can be linked to the smaller size of the company, but is still something that can be strived for today. By having a more informal structure, there are fewer boundaries between colleagues, which can result in a more efficient work process. Employees can communicate directly with the right person and people can work across disciplines if needed. The development was also product focused, during the earlier projects, which improved the possibility of employees helping colleagues, both with their problems and ideas. This organizational structure made it natural for everyone to work together to solve the most critical problems. The project focused development that exists today does not, in the same way, allow working on other projects than one's own.

Attempts of project management tools or methods were also found in the form of SCRUM and Pulse meetings, which were reported to be beneficial and positive for communication and for steering of the development work. These methods are also in line with many other of the aspects described in this chapter, which supports the benefits of using these methods.

Leadership

Many of Mycronic's heads of science helped drive the innovation forward and were a large part of the innovation culture, mostly because they were enthusiastic and knowledgeable. This is important to retain, because this inspired employees to be innovative, thus establishing the innovation culture within the company. Beyond this, leaders should be closely involved with the problems and solutions in the projects to be able to move the project in the correct direction and help when needed. Elevating and enabling employees is also included in a leadership role, giving everyone the opportunity to share ideas with the group. It's further required to have leaders, who take responsibility for making time plans and ensuring that the work progresses. If clear leadership roles are absent, this responsibility instead falls on individual team members, which causes stress, decrease in motivation, and reduced time working with technical problems, which in turn can stifle innovation.

Motivation

Motivation at Mycronic has come from a number of different sources. There has always been external competition towards other companies, in one form or another, which has pushed employees to innovate. Employees got recognition from colleagues, managers and customers for a job well done, there was a sense of pride in the work and every success contributed to this drive to innovate. The challenging and complex nature of the technical problems, along with the high technology level, also posed as incentives. There has also been some economical compensation for patents, yet this has not been motivating for all employees. This can however have played a part in realizing patents as this process required that people put in extra effort and time.

The economic difficulties prior to Mycronic's entrance on the display market led to the development of the company's first mask writer for display manufacturing. Without this product the company could have faced bankruptcy. This provided the company with a serious incentive to innovate. This discussion highlights the importance of motivation as a driver for innovation. This motivation could be different depending on the circumstance, but for Mycronic the most consistent source of motivation has been the challenge, whether technical or economical.

Vision

Visions were used to direct innovation in a desired direction and to provide a goal to work towards. Visions were present in the form of statements, metaphors and analogies. During the Gamer project for example, computer related metaphors and analogies were used to convey the design philosophy. Forecasting of technology and markets also provided visions in the form of e.g. roadmaps that served as a common goal and a sense of direction for the employees.

8.1. Visual representation

A visual framework, which reflects the discussed topics above was then created, see Figure 14.

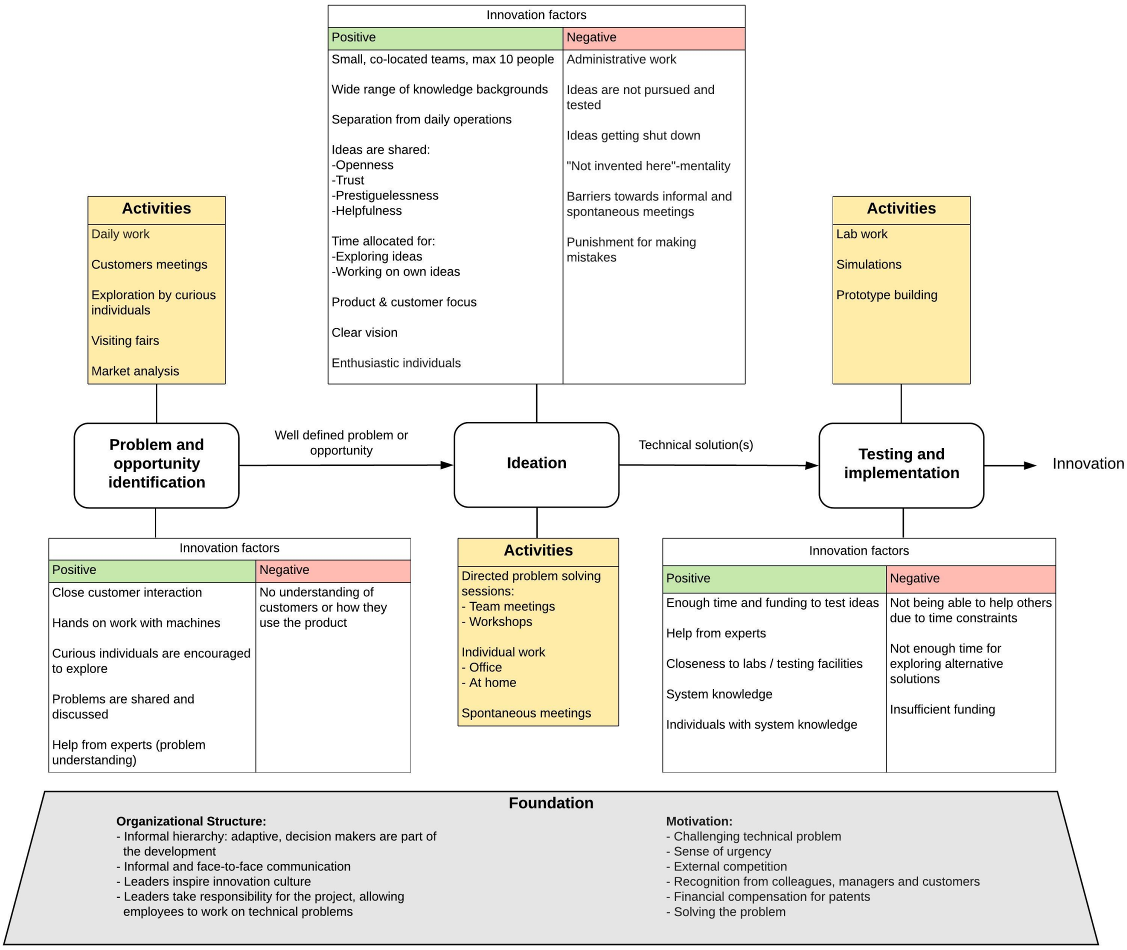

Figure 14, Innovation framework

This framework visualizes the identified stages of how ideas arise, and how these ideas could become innovation. The three identified phases of this innovation framework were; Problem and opportunity identification, Ideation and, Testing and implementation. These three phases are accompanied by activities associated which each phase, which describe important actions that are needed in each phase. For each phase, there are also innovation factors, which could contribute either positively or negatively towards innovation. The foundation describes innovation factors that are necessary for the whole process to function, and are therefore not tied to a specific phase of the process.

The innovation process is depicted as a linear process with clearly defined and discrete steps. In reality this process will, in most cases, not follow a linear work flow. Each step would most likely be more intertwined with each other, with no clean break or separation point to tell when it is appropriate to move on to the next step. This process could also require several loops back to earlier step as new information is discovered. The process was still depicted as a linear work flow to highlight each major step of how an idea was discovered and subsequently improved to, in the end, become an innovation. This layout of the framework allows for a quick overview of the innovation process. This is a desired property since the framework is meant to inspire innovation at a company level, while still retaining a high enough resolution to discern important innovation mechanisms.

8.2. Alternative solutions

During the creation of the framework several alternative solutions were evaluated. It was quickly discovered that the identified innovation mechanisms were tied to different steps, where some were tied to identification of problems and ideas and some to ideation for example. Therefore, solutions that lacked this kind of resolution were discarded. The two alterative solutions presented below, represent two categories of solutions that were developed alongside the final framework.

The first alternative solution represented innovation at the company as a life cycle, see Figure 15.

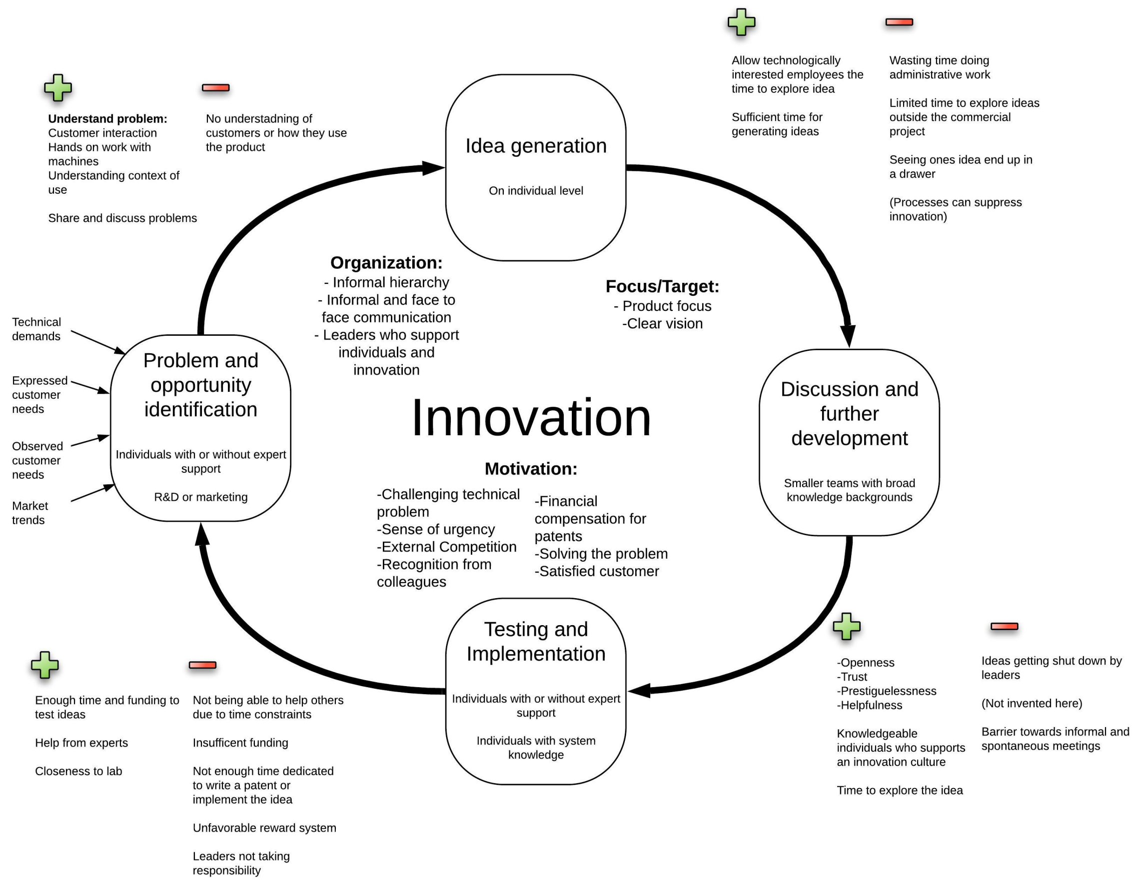

Figure 15: Alternative framework, Innovation cycle

This framework shows a continuous process where innovation is created as a result of this life cycle. Similar to a knowledge process, innovation could evolve over time as problems and opportunities are identified and explored. Unlike a linear process, this framework could perhaps capture many loop backs or reworks that often are associated with development work. However, this framework was eventually discarded since innovation has a beginning and an end, and thus more accurately is represented using a more linear process. Something triggers ideas in individuals, often problems, and these ideas are then explored and tested, followed by an implementation of the idea at which point the idea becomes an innovation.

The second alternative solution was heavily process oriented and is shown in Figure 16 below.

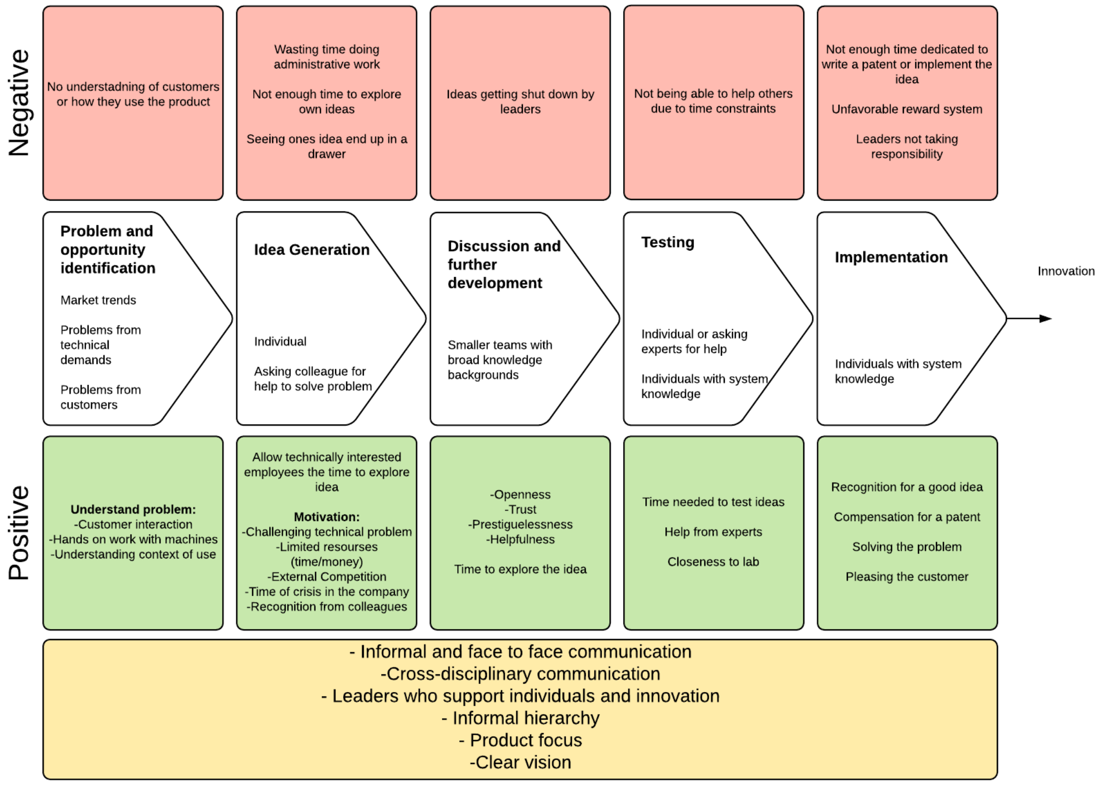

Figure 16: Alternative framework, Innovation process

The problem with this framework was to try to describe the innovation process accurately, while at the same time presenting the information in an intuitive manner. This was an unhelpful resolution of the process, which was neither a totally accurate representation, nor intuitive and easy to understand. This framework also had a larger focus on the process and didn’t focus enough on the innovation mechanisms that were identified. This meant that it wasn’t actionable enough to be used to plan activities aimed at innovation or to describe how one could work to promote innovation during a project.

8.3. Barriers for capture and reuse of knowledge

During the studied projects there was a high degree of personalization, especially during the development of the early photo mask writer, from which virtually no documents exist. This degree of personalization, where most of the created knowledge existed within the individuals who partook in the project, worked well due to low employee turnover. A low employee turnover meant that the knowledge stayed within the company for a long time, and was continuously reused and expanded upon when these individuals started new projects. The company had few employees, and these employees worked closely together and relied on each other’s knowledge. Therefore, the interviewees felt no need to record their knowledge. Even though this level of personalization worked well during this time in the company history, it was not sustainable in the long run. Much of the knowledge these employees possessed could have been lost when they eventually left the company or retired. Another potential barrier towards knowledge reuse with this level of personalization is the difficulty or even impossibility for the knowledge seeker to know who possesses the needed knowledge. Even if this is known, the person with the knowledge could be inaccessible.

The interviewees also felt that there was no official incentive to codify the knowledge created during their work in these projects. The attempts at codification during the more recent of the studied projects appear to have been experienced as more of a chore, rather than something useful. Some interviewees argued that there was no point in trying to codify significant lessons from these projects since no one was going to use it again. Evidence of employees asking for better documentation of test conclusions was also found. This indicates that the test set up and execution was recorded, but actual knowledge, like conclusions of the test was not recorded. Only during more recent days have the employees started to see the value in codifying knowledge for reuse.

Knowledge of incremental improvement was often discarded because these, were not considered to be innovation in the eyes of the employees. Because of this, important knowledge could have been lost entirely, meaning potential rework or repetition of mistakes in the future.

The knowledge that has been codified, mainly related to the radical innovations, is split up into several different databases or discussion forums. There is also no standardized file structure, making it difficult to find the sought information. This means that in order to find the required files in a quick manner, the exact names of these files need to be known. This can hinder the knowledge reuse, which in turn infers that some of the existing knowledge needs to be recreated for every new project, requiring additional time and effort. It's therefore not enough only to store the information, it needs to be sorted or stored in a logical and intuitive way to ease the reuse. Additionally, since the document pathways often are found through asking colleagues, it will become even more difficult or even impossible to find some documents, if these people leave the company.

Several potential barriers which could have contributed to the loss in innovation rate were thus identified. These barriers are summarized below:

- The employees felt no need to codify their knowledge.
- High degree of personalization;
    - Knowledge lost as employees leave the company.
    - Knowledge owner not available.
    - Knowledge seeker doesn't know if the knowledge exists or who has the desired knowledge.
- No official incentive to codify knowledge.
- Not understanding the usefulness of codifying and reusing knowledge.
- Knowledge of incremental improvements tended to be discarded.
- Several databases in use, no way of knowing in which database the sought knowledge could be located.
- Lack of standardized file naming scheme, low searchability.
- Wrong codification focus, the information that was recorded was not useful knowledge.

The studied projects relied on a high personalization level for creating, capturing and reusing knowledge, with scattered attempts at codification. The knowledge life cycle during these projects can be illustrated using Figure 17.

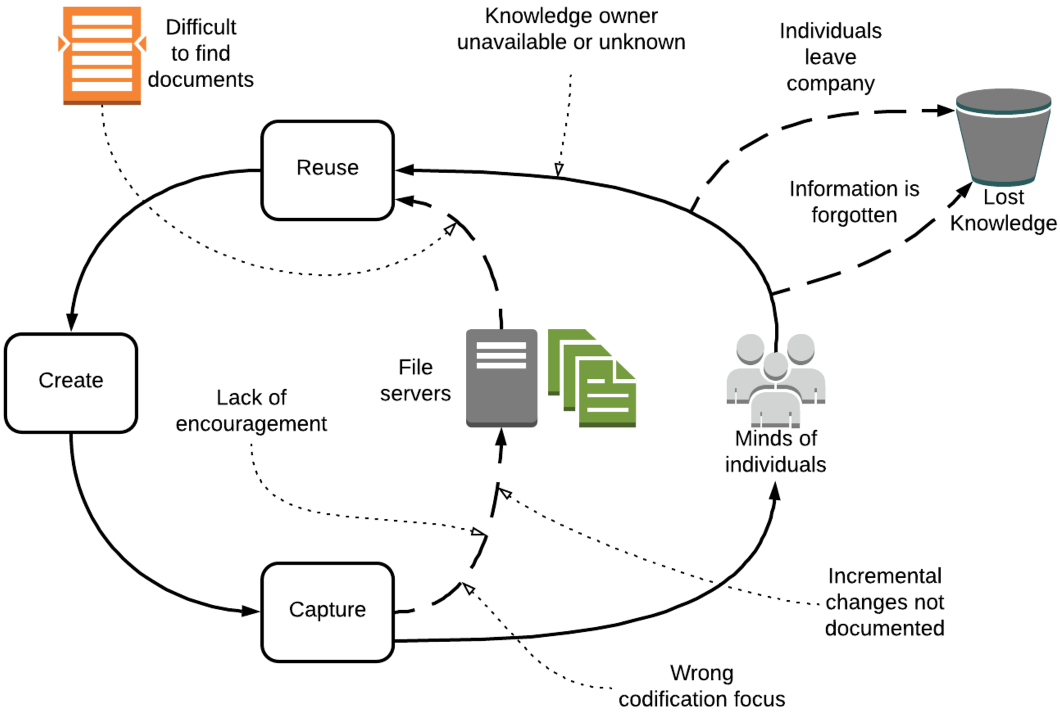

Figure 17: Knowledge life cycle during the studied projects.

Providing a solution for the barriers identified is beyond the scope of this project. However, the identified barriers can serve as a starting point for continued work with KM. Overcoming these barriers could over time improve innovation. Employees also acknowledge that this has been a problem, indicating that there is a willingness in the organization to work more actively with KM.

9. Validation of framework

Because of the time frame of the project, the framework couldn't be tested and evaluated in a real scenario. However, the framework was validated to some degree by comparing it with existing literature. A further method for validation is validation by acceptance, where employees at the company verify that this framework meets their expectations and that it will be used by them in future development efforts. This was performed with the interviewees who participated in the case study.

9.1. Theoretical comparison

Some of the innovation mechanisms that were identified can be directly linked to the theory presented in chapter 5, and some are indirectly linked. The team composition that was found to have been used in the studied projects is well supported by the theory for how innovation is encouraged in development projects. Teams should be small, cross-functional and collocated and group integrity should be maintained for the project's full duration. The face-to-face and informal communication is also crucial. Dialogues have been described as important and both formal and informal dialogues should be encouraged, supporting the usefulness of spontaneous meetings and group discussions. An accepting and trusting atmosphere is also tightly connected to this notion and is important for the success of knowledge management efforts and thus also for innovation.

In the theoretical framework, it was also described that strict hierarchies aren't well suited for innovation, which supports the applicability of informal hierarchies and their contribution to innovation in Mycronic's past. Organic organizational structures foster creativity and explorative thinking better than a mechanistic organizational structure, and thus the informal hierarchy is well suited for this purpose. Having a customer focus in the development efforts and understanding customer needs is also relevant in relation to innovation. Additionally, the theory suggests that enough resources need to be allocated to research and that funding should be matched to projects in a meaningful way. This validates the fact that enough resources need to be allocated to the projects so that for example alternative solutions can be explored properly.

Furthermore, competition between companies has been mentioned as being both beneficial and inhibiting for innovation, depending on the circumstances. Therefore, external competition can also have been important for the innovation, since there was an outside pressure to innovate, which acted as a motivation. Moreover, it's critical to have driven and enthusiastic people in the team, along with motivated and knowledgeable leaders, who take responsibility and guide the innovation in a desired direction. Having a clear vision is also described as being important for providing a sense of purpose and a clear direction throughout the organization.

9.2. Validation by acceptance

The framework was sent to the interviewees who participated in the case study. Their feedback was then used as a kind of validation for the framework. Most of the received feedback was positive and the interviewees said that there was a familiarity with what was described and that it represented the process well. Some also said that it can be used for planning of activities that foster innovation. There was some specific feedback on parts of the framework that were appreciated and also some feedback for small adjustments. These adjustments have been taken into account in the finished framework, but no major overhaul of the framework was required.

10. Discussion

This thesis was primarily conducted at Chalmers University of Technology, with only a few visits to the company headquarters in Stockholm. The geographical distance between the two sites could have created two barriers towards implementing the framework. The first one being that, the company was not part, or had full insight in the development of the framework. This means that the company themselves did not develop this framework, and thus could miss, through no fault of their own, important insights which can only be obtained during the creating of the framework. Secondly, it reduced the communication exchange between the authors and the company, which could have diminished the knowledge gain of both parties. Despite the geographical distance, and these potential problems, the cooperation worked well. However, being collocated for this type of thesis work, could further have improved the result.

The choice of method to answer the research question was limited to interviews and document studies. This choice was primarily based on that this thesis investigated historical events, making methods like observation not a viable choice. A suitable alternative method could be the use of focus groups where employees could be presented with a topic and freely discuss with their peers. However, this could potentially lead to situations where certain participant did not feel safe to raise their concerns. Another reason for not using focus group was that it would not make the case study anonymous. Anonymity was even something interviewees requested before taking part in the study; this made interviews a suitable method. Questionnaires could also have been suitable if more was known about the different innovation mechanisms going into the study. This is because questionnaires are of a more confirmatory nature. However, since the aim was to explore the topic and to dig deep into complex relationships and processes, therefore this method was not chosen

The case study was solely focused on projects conducted at Mycronic, no other company was investigated. The investigation was primarily limited by the time frame of this thesis; there was not enough time to expand the investigation to include multiple companies. However, most of the discovered innovation mechanisms could, in some manner, be supported with the theoretical framework presented in this thesis. Even though the innovation process, which includes; Problem and opportunity identification, ideation and, testing and implementation, could vary depending on company and industry, the identified mechanisms could still be applied in a more general sense. Despite the attempts at generalizing the framework, the result still relies on data from one source, namely Mycronic. It is therefore recommended that more companies are investigated in the future to further strengthen, or disprove the innovation mechanisms discovered during this thesis.

The case study was performed without first identifying which historical projects were deemed innovative. This was, in part, because the knowledge, of which projects were considered innovative, was unknown to the authors at first. Another reason was so that the interviewees themselves could explain which project they found innovative. It was believed that this would allow the interviews to more freely explore what was important for innovation on a personal level. This tactic allowed the authors to identify four cases which the interviews naturally converged to. These are the projects presented in chapter four. An alternative approach, where innovative projects were identified before starting the case study, could have been used. This approach could have allowed a more directed exploration of each project, with targeted interviews with people who were part of these projects. However, this approach could have missed, in part, what interviewees considered important for innovation by leading the questions towards what the author considered to be innovative.

By deciding on keeping the interview results anonymous, interviewees might have been more open compared to if these results would have been used as quotes, directly linked to the involved people. Because the authors served as outsiders, this effect can have been even further enforced, resulting in a more accurate and truer picture of the work during the time of the studied projects.

The choice of using semi structured interview was used since, as previously mentioned allowed the interviewees explore what they considered important for innovation, while at the same time staying within certain predetermined topics. This interview tactic worked well and allowed for the identification of important innovation mechanisms. However, a drawback of this approach was a difficulty to sometimes link certain discussions to specific projects. This difficulty arose due to the great time span of the case study and because interviewees often had been part of more than one of the studied projects. This is believed to not have affected the identification of important innovation mechanisms, merely in which projects they were present or absent. The authors' inexperience of probing can in large part have affected this and the problem could have been reduced through better interviewing techniques.

The layout of the framework was chosen to provide a quick overview of the innovation process. The innovation process is complex and does not follow the linear work flow depicted. A framework with a higher resolution of this process could therefore have been made. A higher resolution would also provide a more accurate description of the steps involved in this process and how they are connected. Potential loopbacks or iterative work flows could also have been represented. However, a framework of this kind would quickly become complex and lose its ability of providing a quick overview.

The validation of the framework, which was part of RQ3, could only be done in part. The time frame of this thesis did not allow a full validation by applying the proposed framework during a real scenario or project. Testing how the framework performs under real conditions is therefore recommended as the next validation step before applying the framework throughout the organization. Even though the framework could not be tested during a real scenario, opinions and feedback from interviewees still served to partially validate the frameworks applicability in the company. However, the response rate from interviewees was relatively low, which could potentially provide a skewed image of how this framework was perceived. It could therefore be useful to have more employees provide feedback on the content of the framework before attempting validation through a real scenario.

Another consequence of not validating the framework in a real scenario was that it was difficult to establish in what scenario and by whom the framework should be used. The authors suggest that the framework can be used as a general innovation guide used by executives to foster innovation in the long term. Another area of use could potentially be when planning R&D activities such as establishing teams, specifically aimed at innovation. It can also be used to foster innovation through highlighting innovation sources, such as allowing creative individuals the resources to work on their own ideas. The framework could be used by project leaders or managers, who want to increase innovation or set up an innovative environment in a project. The potential uses for the framework could not be evaluated within the time limit of this thesis and is thus left as recommendations for future work by the company.

The investigation towards barriers, which could have prevented the reuse of knowledge from these projects, was done from a KM perspective. This approach was of interest to the company since this is an area in which they want to improve. The company therefore wished to investigate if barriers towards KM in these projects could be responsible for the decline in innovation today. The decline could perhaps be linked to other factor than only a lack of knowledge reuse. The products are more mature today compare to the time period studied during this thesis. This could mean that a larger effort in terms of engineering hours is needed to achieve an increase in performance and thus slowdown innovation. Even though a lack of knowledge reuse could be a contributing factor towards a decline in innovation, it is unlikely the only one. It is therefore recommended to investigate if other factor could have contributed towards the decline in innovation.

11. Conclusion

The case study at Mycronic, and subsequent analysis of the result of this study, allowed for the identification of four cases which were considered highly innovative, and the identification of why these cases with related projects were innovative. The case study also revealed barriers which could have contributed to the reduced innovation rate experienced by the company today.

The created visual framework illustrates an innovation process based on the studied projects. The framework also illustrates important innovation sources in the form of "activates" and what could affect this creative process in a positive or negative way. Using the framework could provide a guide of how to organize part of the development effort in a way that fosters innovation, or improve the existing innovation culture within the company. The framework could thus provide a way of turning around the declining innovation rates experienced by the company today.

The validation of the framework proved many connections with the theoretical framework presented in this thesis. This indicates that the created framework could be used in a more general manner, both in other companies and industries. The validation also revealed that employees agreed with content presented in the framework, and only minor changes were needed to clarify the presented information.

The barriers were identified from a knowledge management perspective. The case study revealed a high degree of personalization during the studied projects. Any useful knowledge exists within individuals and was reused and expanded upon when these individuals started a new project. Individuals who sought knowledge regarding previous projects preferred to ask individuals, who they knew had been a part of these projects. This degree of personalization appears to have fostered innovation as long as the knowledgeable individuals remained in the company. However, many of these individuals have now left the company and much of their knowledge is lost. Therefore, this degree of personalization could have been, in part, responsible for the decreasing innovation rates.

The scattered attempts at codifying knowledge during these projects appear to have been in vain. Much of the information from this time was never intended to be reused in a KM sense, making it difficult to use this information. Desired information regarding these projects is also difficult to find since it is spread out over several databases and has no standardized file naming scheme. These difficulties explain why employees prefer to seek knowledge directly from colleagues, rather than searching though databases.

Transforming the organization into a knowledge organization requires time and resources and will have to involve the entire organization, especially management. However, these identified barriers provide a place from where to start. By working towards the elimination of these barriers it is possible to increase the innovation in the company over time, and prevent this situation from happening again.

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Appendix

Appendix 1 – Time schedule

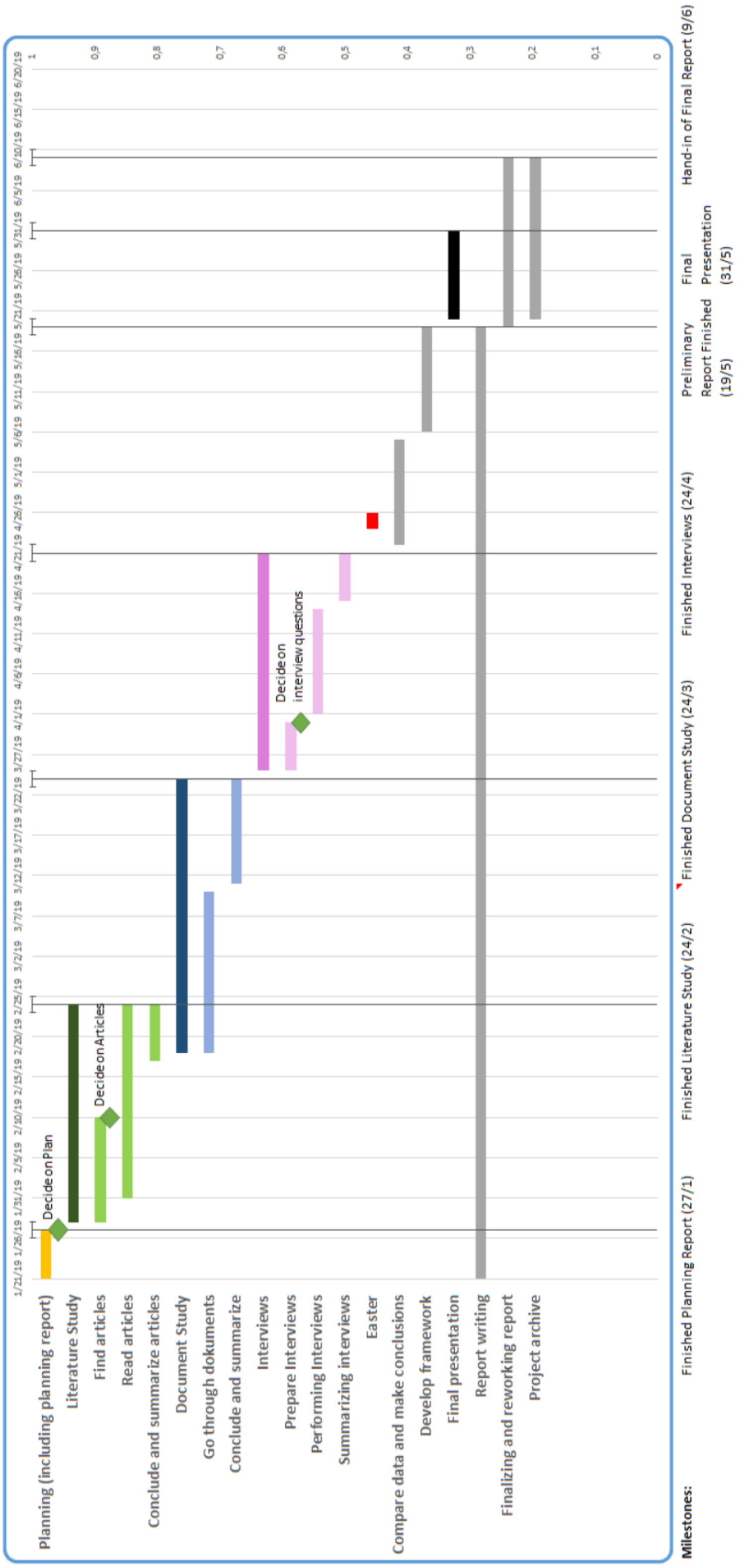

Figure 1: Gantt schedule

Appendix 2 – Interview guide

Intervjuguide

Tid: 45–60 minuter

Respondentens namn: …..
Nuvarande jobbtitel: …..
Dåvarande jobbtitel: …..

Datum: …...
Intervjunummer: …..
Intervjulängd: …..

Verktyg

Mobiltelefon för inspelning

1. Inledande frågor

1.1 Vilka innovativa projekt har du deltagit i historiskt? (Ge exempel på innovation)

1.2 Vad handlade projektet om?

1.3 Vad var din roll i det här projektet?

1.4 Vad hade du för arbetsuppgifter?

1.5 Hur såg en normal dag ut under projektets gång?

2. Organisation

2.1 Hur många var involverade i de tidigare projekten? (Könsfördelning? Kunskapsområden? Kultur?) **Hur påverkade detta arbetet?** (lättare att organisera? få kunniga personer? För många viljor?)

2.2 Kan du beskriva arbetsmiljön?

- Lokaler. (Hur tycker du att detta påverkade kommunikationen med andra delar av företaget?)
- Utrustning

- Support från ledningen?
- Support från kollegor?

2.3 Hur var organisationsstrukturen? (Tydlig hierarki? Organisk struktur?)

2.4 Fanns det ett tydligt ledarskap? Någon som tog lite extra ansvar?

2.5 Hur kontrollerades framsteg och tider? (gate/milestones)

3. Innovation

3.1 Hur uppkom idéer?

3.2 Hur arbetade ni med innovation?

3.3 Vad anser du vara de viktigaste faktorerna för innovation i dessa projekt? Vilket var det absolut viktigaste?

3.4 Vad fanns det för incitament som motiverade innovation?

3.5 Var det enskilda individer som stod för idéer eller var det en "group effort"? Varför?

3.6 Fanns det tid att jobba med egna idéer utanför projektet?

3.7 Var det personligt gynnsamt att dela med sig av idéer eller höll man det gärna för sig själv?

3.8 Hände det att man INTE gick vidare med bra idéer? Varför? Vad hände med dessa idéer?

3.9 Varifrån kom problemen? Hur identifierades dem? Exempel? Från: tekniska krav in till projekten, från kunder, från konkurrenter, från observationer, idéer som sökte ett problem.

3.10 Var det identifierade problemet väl känt eller begränsat till ett fåtal personer? Varför?

3.11 Var det samma personer som identifierade problemen som också stod för lösningarna? Varför?

3.12 Arbetade man mycket på sina egna projekt eller hjälpte man gärna andra? Varför?

3.13 Hur kommunicerades problem/idéer mellan kollegor? Vilka hjälpmedel användes?

4. Human factors / Kultur

4.1 Hur var drivet i projektet? Var det ett spännande projekt? Varför?

4.2 Fanns det en tydlig vision? Vad var företagets vision?

4.3 Hur var stämningen mellan kollegor och eller ledningen?

4.4 Hur var stressnivåerna under det här projektet?

5. Teknologi

5.1 Vad för typ av IT-support fanns?

5.2 Hur kommunicerade man? Vilka kommunikationskanaler användes?

5.3 Vilka programvaror användes?

6. Omgivande faktorer (Environment)

6.1 Hur var konkurrensen? Hur påverkade detta innovationen tror du?

6.2 Hur var efterfrågan för dessa produkter? (Tydliga kundkrav eller mer oklara behov? Länder?)

6.3 Hur upplevdes teknologin av ert team och av allmänheten på den tiden?

7. Knowledge Management

7.1 Hur bevarades lärdomar och kunskap från dessa projekt? (ifall nej, varför tror du att denna kunskap inte bevarades?)

7.2 Ifall ja,

- Hur uppmuntrades man till att ta vara på lärdomar? Fanns det rutiner för att ta vara på denna kunskap?
- Hur spred ni dessa lärdomar till resten av organisationen?
- Hur återanvänds den här kunskapen idag? Är den uppdaterad?
- I vilka situationer passar det att använda den här informationen?
- Hur gör du för att hitta information om de här gamla projekten? (Om jag skulle be dig ta fram information, hur skulle du göra?)

8. Annat

8.1 Varför tror du att det här var ett lyckat projekt?

8.2 Vad var det bästa med projektet? Varför?

8.3 Vad hade kunnat förbättras? Varför?